ECHINODERMS OF THE IOWA DEVONIAN

BY

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ECHINODERMS OF THE IOWA DEVONIAN

Introduction

It has been nearly eighty-five years since David Dale Owen collected and reported the first echinoderm remains from the Devonian rocks of Iowa. Since that time additional contributions to our knowledge of this interesting group of animals have been made by almost a score of students of the life remains found in these rocks within the state. The published accounts of their findings are widely scattered and in most cases are available only to those who have access to large libraries stocked with various state and government reports.

It is the purpose of this paper to bring together this scattered literature, thus better to preserve the work of the pioneer scientists, to amplify their observations in the light of later and fuller discoveries, and to add such new material as remained undescribed in the collections of the late Dr. Samuel Calvin together with a number of new species secured by the writer during his study of the Iowa Devonian for the State Geological Survey, and finally many fine species have been freely contributed for study by several people, acknowledgment of which is made in the body of the report.

The species described are distributed over twenty-two genera and belong to forty-three species and two varieties. Of the genera, two are new and seven others have not been previously reported from the Devonian of the state. Twenty-four of the species and the two varieties are new. All have been illustrated in a series of twenty plates and a number of text figures. Illustrations of a few species occurring outside the state have been introduced for comparison. In the classification, Zittel's Textbook of Paleontology, second edition, has been followed in the main. The writings of Wachsmuth and Springer on the camerate crinoids, of Springer on the flexible crinoids, and of Jackson on the echinoids have been freely consulted. Bather's paper on the Triassic Echinoderms of Bakony has also proved very helpful in interpreting the dissociated echinoid material. Genera which are new or peculiar

to our area have been more or less fully described. The museum location of types is cited in all cases where it is known.

Previous Work on the Echinoderms of the Area

As intimated above it was Dr. David Dale Owen, commissioned as "Principal Agent to explore the Mineral Lands of the United States", who first observed echinoderm remains in the Devonian terrane of the Iowa territory. This was in 1839. In the revised report published in 1844, on page 32, is a statement that "About three miles west of Rockingham, in Iowa, occur strata abounding in *Entrochites* and *Reteporae,--*". On plate xi are illustrated two weathered slabs which "display on their surface a variety of *Entrochites* and *Reteporae;* also, a Tentaculites and a new coral *Cyathopora Iowensis,* O." Owen was of the opinion that the rock was Carboniferous limestone although he "did not obtain unequivocal evidence." The slabs illustrated can be duplicated at many points in the Cedar Valley limestone all the way from Muscatine county, where Owen collected his, to Johnson county and on north to Bremer county. The fossils on Owen's slabs are stem segments presumably of *Megistocrinus;* the bryozoa which he thought to be bits of the fronds of *Archimedes* are parts of a *Fenestella,* of *Cystodictya hamiltonensis* Ulrich, and of others; the *Tentaculites* is *T. hoyti* White; while the coral is now referred to *Cladopora iowensis* (Owen). In his 1852 report, page 85, Owen made the correction and referred the beds to the Devonian. In the latter report this shrewd observer mentions finding *Hexacrinus* and *Olivanites* (*Nucleocrinus*) at Davenport and below Rockingham, respectively. These are the first echinoderm genera identified from our Devonian rocks and it is interesting to note that these localities furnished the types of new species in each genus as will be noted later in this paper.

In 1858, James Hall's well known report on the Geology of Iowa appeared in two parts. This contains the results of the investigations made by him and his staff during portions of the years 1855-1857. It is not necessary here to dwell on his interpretation or mapping of the Devonian of the state,

suffice to say that in its larger features the work is surprisingly accurate. He emphasizes the Encrinal limestone along the river south of Davenport (pp. 86, 87) and notes a species of *Pentremites* and numerous fragments of crinoids and crinoidal columns in the vicinity of (New) Buffalo. In the paleontological part of the report he described and illustrated one new blastoid, *Codaster subtruncatus,* and three new crinoids, *Megistocrinus latus, Taxocrinus interscapularis,* and *Synbathocrinus matutinus,* all from the beds about Buffalo. Again in 1861 we find Hall including a crinoid from Iowa City with other similar crinoids from Milwaukee, Wisconsin, and describing them under the name *Melocrinites nodosus.* In passing it may be noted that Hall contributed much to the early knowledge of the Burlington crinoids of Iowa and his descriptions, illustrations, and diagrams of these prove him to be a keen observer and a clear writer.

One of the most enthusiastic students of paleontology, an indefatigable collector, and one who was unusually careful in the preparation and preservation of his specimens was the Rev. W. H. Barris. Trained for the ministry but with a strong leaning toward natural history he was called from his first charge at Brockport, New York, to become rector of Trinity Church at Iowa City. This was in 1855 and the Devonian of Iowa was then virgin territory. Here he must have met Hall who spent a few weeks at Iowa City in the autumn of 1855. At any rate during his four-year charge of the parish we find him sending choice specimens to Hall and others and gradually acquiring a knowledge of the local geology. From Iowa City he was called to Burlington where many of his spare hours for seven years were spent in making a collection of his favorite fossils, the crinoids. It was here that he met Wachsmuth and from him the latter acquired his first knowledge of geology and paleontology, a knowledge which bore such abundant fruit in later years. From Burlington, Barris was called to Davenport where he spent the remainder of a busy and useful life. Here he kept up his paleontological interests and continued writing papers on geology and paleontology, a work which he had already begun at Burling-

ton. At Davenport he studied especially the Devonian blastoids and his contribution to the knowledge of this class ranks among the best done in America. His frequent excursions to northern Michigan resulted in the discovery about Alpena and elsewhere of many specimens of blastoids identical with those found at Davenport and serving as indexes for the correlation of the Devonian of the two areas. Nor were the crinoids of the region about Davenport neglected in his devotion to the blastoids. The fact that he found a large number of almost perfect specimens in an area where crinoidal remains are especially fragmentary is a testimony to his untiring energy. His new genus *Stereocrinus* and the species of the following list are from the Iowa Devonian:

Nucleocrinus obovatus
Nucleocrinus meloniformis
Stereocrinus triangulatus
Stereocrinus triangulatus var. liratus
Megistocrinus nodosus.

Two of the species described in this report have been named in his honor and he collected the types of others. Frequent allusions to his contributions occur under the description of species, in the following pages.

Dr. Chas. A. White, state Geologist of Iowa from 1866 to 1870, was a paleontologist of much ability. Being a resident of Burlington for many years, where he knew Barris and Wachsmuth intimately, his chief paleontological work in Iowa naturally was done with Mississippian, especially with Kinderhook, fossils. However, in a paper by him in the Proceedings of the Philadelphia Academy we find the description of a new Devonian genus of cystids, *Strobilocystites,* and of the species *S. calvini* named for its finder Doctor Calvin who found the types near Iowa City. In the same paper White described the crinoid *Megistocrinus farnsworthi,* a rare species also from the vicinity of Iowa City.

It is not surprising that Prof. A. H. Worthen, who assisted Hall with his Geology of Iowa, should have been familiar with the Iowa Devonian. Worthen was later State Geologist of Illinois. Inasmuch as the Devonian of Iowa extends across

the river in the vicinity of Rock Island, Worthen, in the pursuit of his studies of the Illinois Devonian, collected fossils on both sides of the river. Two species of crinoids described by him in the Illinois reports are from the Iowa side, one, *Deltacrinus barrisi* from Davenport, and the other, *Poteriocrinus buffaloënsis,* from a ravine near Buffalo. Some years earlier he and Prof. F. B. Meek had described *Eutaxocrinus gracilis* in the Proceedings of the Philadelphia Academy. The type specimen of this species also came from Buffalo.

The names of Wachsmuth and Springer will forever be associated with American echinodermology. Their great monograph on the Crinoidea Camerata includes all North American crinoids of that order known up to the time of its publication in 1897. The noted Burlington beds furnished the greater part of their extensive and beautiful collection of crinoids. Wachsmuth lived at Burlington where Springer came to practice law upon his graduation. The happy association of these two men, their profound knowledge of these interesting fossils, and their friendly attitude and helpful suggestions, drew paleontologists and collectors to them in fullest confidence. Wachsmuth was ever ready to aid others where he could, Springer generously passed an opinion on any specimen sent or brought him for identification. In the collections at the University of Iowa are many fine blastoids and crinoids obtained by Calvin from one or the other of these two men, while a magnificent collection of the Burlington crinoids was presented to the University by Doctor Springer several years ago. On the other hand Professor Calvin delighted in referring such crinoids as he found to them for determination and study. The writer recalls a fine flexible crinoid collected by Calvin in the Hamilton shale at Thedford, Ontario; in due time he apprised Springer of his find and years later the specimen appeared as a cotype of one of Springer's new species. From the Iowa Devonian three new camerates were described in Wachsmuth and Springer's famous monograph. These are *Melocrinus tiffanyi, Melocrinus calvini,* and *Hexacrinus occidentalis.* They were collected respectively by A. S. Tiffany at Buffalo, by Samuel Calvin at Solon, and by W. H. Barris at Davenport.

In Dr. Frank Springer's recent monograph on the Crinoidea Flexibilia appears a description and illustration of a remarkably fine new species, *Euryocrinus barrisi,* from Buffalo. Three other flexible crinoids from our Devonian have been admirably illustrated and redescribed in this scholarly treatise.

Dr. Samuel Calvin, head of the department of geology at the University of Iowa for close to forty years and state geologist for nearly twenty years, was a close and critical student of the Iowa Devonian. He prepared the greater number of the reports of the counties where the Devonian belt outcrops and made extensive collections of the fossils, among them being six of the new species of this paper. Most of these were accumulated subsequent to the appearance of the Monograph on the Camerata. In spite of a busy life in the class room, in the field, and in the pursuit of various duties related to the administrative functions of his offices as state geologist and department head, he found time to describe a large number of fossils. This Calvin did so well that it is regrettable that he did not have ample time to devote to the study of his collections. Only one echinoderm, a cystid, *Strobilocystites polleyi,* was diagnosed by him. This was collected by one of his students in the Devonian of Cedar county. The chief contribution of Calvin, however, was not in the new species he described, nor in the geological papers and reports which he wrote, excellent as they were, but in the inspiration and enthusiasm he imparted to his students.

Many others have contributed in a more or less direct way to the literature of the subject. Prof. R. P. Whitfield, for example, published the first illustration of *Melocrinus nodosus.* Mr. A. S. Tiffany in a paper on the "Geology of Scott County, Iowa, and Rock Island County, Illinois," published in 1885, listed a great many species from the Devonian, among them ten genera, some with "undetermined or new species," and nine species of blastoids and crinoids. Most of these, however, appear to have been incorrectly identified, at least most of them do not occur on the Iowa side and in Mr. W. E. Ekblaw's paper on the "Correlation of the Devonian System of the Rock Island Region," published in 1912, no echinoderms are listed. Vari-

ous papers by Mr. C. L. Webster refer to the occurrence of crinoids in the Devonian rocks of the state; allusion to his reporting a *Strobilocystites* from Floyd county is made under one of the species of that genus. Mr. C. L. Fenton's list of "Hackberry" fossils includes one genus of crinoids and one of echinoids.

In 1919 the writer read a preliminary paper before the Paleontological Society of America on " Echinoderms of the Iowa Devonian." It appeared in abstract form in the Proceedings of the Geological Society of America for 1920, pages 211, 212. In this are presented briefly some facts concerning the echinoderms already described; the genera *Arthracantha, Dactylocrinus, Decadocrinus, Cyathocrinus,* and *Xenocidaris* are reported for the first time; and a brief diagnosis is given of two new genera of echinoids, namely *Devonocidaris* and *Nortonechinus.* The *Dolatocrinus* mentioned in the abstract has proved to be a *Stereocrinus* and the doubtful *Lecanocrinus* turns out to be a new species of *Clidochirus.* In the same year the writer read two short papers bearing on the Iowa Devonian before the Iowa Academy of Science; one on "The Fauna of the Independence Shale," pointing out among other things the occurrence of *Arthracantha* in Iowa, and the other on "*Nortonechinus,* a Devonian sea urchin." Abstracts of these appeared in Science, July 23, 1920, p. 89. At the meeting of the Iowa Academy of Science in April, 1923, another paper was read entitled "The Geographic Distribution of Iowa Devonian Echinoderms." The chief points in the paper had already been prepared for, and they appear in, this report.

What Echinoderms are and which are represented in the Iowa Devonian

Echinoderms are invertebrate animals that have always lived in the sea. Common examples known to most people are the crinoids or sea-lilies, the starfishes, and the sea-urchins. Scientists make three groups of them and these are again considerably subdivided. They are: I. PELMATOZOA, which with a few exceptions are fixed by a jointed and flexible stem during their post-larval life—here belong the cystoids, blastoids,

and crinoids. II. Asterozoa, which have star-shaped bodies and are stemless and hence have freedom of movement over the sea floor. The well known starfishes and brittle stars are assigned to this group. III. Echinozoa, which are free and without arms, their bodies being globular or heart-shaped as in the sea-urchins, disc-shaped as in the sand dollar, or enclosed in an elongate leathery integument, an example of which is the sea-cucumber.

Echinoderms have had a very long geological history as is shown by the fact that their fossil remains are found in some of the oldest rocks known to contain organic remains. Their progress from early times down to the recent is a fascinating story—now one class and later another is in the ascendancy—here the rocks are filled, literally crowded, with their skeletons, there not a trace of any of them is found. Of the seven classes two of them, the cystoids and blastoids, are extinct. They were limited to the Paleozoic. The cystoids thrived in the Ordovician and Silurian and had become very rare in the Devonian, a fact which adds interest to the species of Iowa *Strobilocystites* which are found in the highest beds in which rhomb-bearing Cystoidea are known to occur. The blastoids, however, continued on beyond the Devonian and culminated in the next period. Of the four orders of crinoids, two of them, the Camerata and Flexibilia, disappeared before the end of the Paleozoic, the third order, the Inadunata, continued on into the Mesozoic, while the last, the Articulata, began about the close of the Paleozoic and contains all the living crinoids. Fossil representatives of the first three orders occur in the rocks embraced in this study. The Asteroidea, or starfishes, which are abundant to-day, may be traced back to Cambrian times. No remains of these or of the next have been found in the Iowa Devonian. The brittle stars, or Ophiuroidea, are common in the modern seas but their fossil record, though dating back to early Paleozoic, is meager. The Echinoidea, or sea-urchins, have been a part of the world's marine fauna from the Ordovician to the Recent. They have been especially abundant during the Mesozoic and Cenozoic. Their Paleozoic evolution is a fascinating story and it is a pleasure to add not a little to that

account in this paper. One order, the Perischoëchinoida, is represented in the Iowa Devonian by three genera and five species. The Holothuroidea, or sea-cucumbers, because of their poorly developed skeletal parts, have left but a very scant paleontological record. However, Walcott has undoubted specimens from the Cambrian of British Columbia and there are straggling bits of evidence down through the geologic eras connecting those early representatives with the modern forms.

The classes, orders, and families of echinoderms found in the Devonian of our area may be arranged in tabular form as follows:

Classes	Orders	Families
Cystoidea	Rhombifera	Callocystidae
	Edrioasteroidea	Agelacrinidae
Blastoidea	Eublastoidea	Codasteridae
		Nucleocrinidae
Crinoidea	Camerata	Melocrinidae
		Batocrinidae
		Hexacrinidae
	Flexibilia	Ichthyocrinidae
		Taxocrinidae
	Inadunata	Synbathocrinidae
		Cremacrinidae
		Cyathocrinidae
		Poteriocrinidae
Echinoidea	Perischoëchinoida	Archeocidaridae
		Lepidocentridae

Preservation and Abundance of the Echinoderm Remains

The echinoderm remains in the Iowa Devonian are scanty when compared with the prodigal abundance of the same class of remains in the overlying Mississippian strata as exemplified in the classical localities at Burlington, Keokuk, Le Grand and elsewhere in the state. Yet certain zones in the Devonian are so filled with crinoidal remains that they form "encrinal" or crinoidal limestone. In fact stem ossicles of crinoids are common fossils at nearly every locality where fossils of any kind occur. Good calyces, however, are rare and are not confined to any particular locality, although, in general, the ravines in the vicinity of Buffalo, Scott county, the *Megistocrinus* beds near Solon, Johnson county, and certain layers to be pointed out more fully later near Brandon have produced many fine specimens. To these may be added certain layers of argillaceous limestone near Iowa City, a patch of weathered limestone

in the suburbs of Waterloo, and a few exposures of the Lime Creek beds in Floyd and Cerro Gordo counties. Other less important horizons will be mentioned under the discussion of the different species.

With few exceptions the specimens studied are preserved as calcite in the limestones or shales. The readiness with which this mineral splits along its cleavage planes makes both the removal and the cleaning of specimens difficult and tedious. The task, for example, of cleaning the specimen described as *Melocrinus nodosus irregularis* required many hours of very close work since when it was found only five or six of its nodose plates were free from the tough hard matrix. As a rule, however, careful work is rewarded by the uncovering of traceable sutures, which are quite necessary for the correct identification and elucidation of the specimen. In the case of specimens where the sutures are too faint for photographing they have been traced in ink.

The specimens of *Megistocrinus clarkei* from Waterloo are silicified as is also the type of *Melocrinus linderi* from near Iowa City. Except for the type specimens of *M. clarkei* and *Hexacrinus occidentalis* none of the camerate crinoids studied preserves the arms. The preservation of the arms and in some cases bits of the stem is the rule, however, among the flexible and inadunate species.

In all cases where possible, strata containing abundant crinoidal or similar fragments have been traced laterally and in a few cases small areas have been located where the stratum is weathered into a marly shale. These places are a collector's bonanza. If quantities of such material are sifted through a set of fine-meshed sieves placed one above the other—the coarsest above—a large quantity not only of echinodermal fragments but of other small fossils as well may be found. A zone near Brandon yields an abundance of the nodose plates of *Megistocrinus pernodosus,* another below Nora Springs yields plates of *Hexacrinus springeri,* while surprisingly good results have been obtained in the different zones of the Lime Creek shales.[1] Here parts of echinoids have been found; teeth, braces, and

1 Bull. Geol. Soc. Amer., vol. 32, pp. 130,131; 1921.

other parts of the lantern as well as delicate ambulacral plates and spines were thus recovered. At several localities in the Lime Creek a quantity of the plates of *Clidochirus iowensis* may be obtained; from such a lot the author has selected a set which if united would make a fairly good reconstruction of the calyx to the bases of the arms, see plate XLIII; it should be added that several sets of the attached infrabasals have been obtained which aided materially in a proper understanding of the species. From the Independence shale but three or four radial plates of an undoubted *Arthacantha* were collected. On the basis of these a new species is described. Now the question can properly be asked as to what extent may species or genera be founded on dissociated parts of crinoids or echinoids. The author is well aware that it is possible to go too far in establishing species on insufficient material, perhaps he has done so, but here are the fossils and some names are needed in order to use them. It is conceded that the radials of an *Arthacantha* or of a *Cyathocrinus* or the spines and plates of an echinoid are much less desirable than complete specimens. But complete specimens have been sought more or less in vain. The next visit may yield one and then it will be seen to what extent we have erred. At any rate years have elapsed in the preparation of this paper partly at least because the hope has been entertained that more or less complete specimens eventually would be obtained. This actually happened in the case of one of the echinoids when Mr. C. H. Belanski found a part of an interambulacrum of *Nortonechinus welleri*. It was a thrilling discovery and the finder deserves great praise for his persistence. However, a study of the loose plates and spines mounted on a ball of modeller's clay had determined beforehand the mode of imbrication of the plates, the position and relation of the spines, and other facts. The accuracy of the restoration was almost wholly corroborated by the arrangement of the plates and by the position of a few spines held by the matrix to the piece of interambulacrum. This is not an argument that dissociated material can be restored in all cases, indeed, in many instances it is hazardous to attempt it at all. The writer, however, does want to make the point that where material is

distinctly different from any with which it is associated and when it possesses unmistakable characters such as the arm facet on the radial of a *Cyathocrinus* or the spine sockets on the radial of an *Arthracantha* generic recognition is certain. And, too, when these dissociated parts are limited to a more or less distinct zone and are geographically remote, as is the case with *Arthracantha,* from other species of the genus then specific rank can be assigned with reasonable safety from duplication.

A few illustrations of unidentified forms such as stem segments, parts of calyces, and so on, have been entered on one or two plates. The number might have been extended but enough have been introduced to show that there are other species awaiting the student when better material is obtained.

The Distribution of some of the Genera and Species.

Of the forty-three species and two varieties described in this paper only seven of the species are reported as occurring outside the state. These are:

Nucleocrinus obovatus	Iowa, Wisconsin, Michigan.
N. meloniformis	Iowa, Michigan.
Melocrinus nodosus	Iowa, Wisconsin.
Megistocrinus nodosus	Iowa, Michigan.
Euryocrinus barrisi	Iowa, Michigan.
Synbathocrinus matutinus	Iowa, Michigan.
Deltacrinus barrisi	Iowa, Illinois.

It is to be noted that these species do not range far beyond the confines of the state and are practically limited to the Dakotan sea and Traverse basin of Schuchert.[2] It may be expected that when the faunas of these basins are better known the above species will be found to extend more widely and that the range of other species here described will spread beyond their present known limits. Indeed, closely allied if not the same species do occur in the Missouri Devonian (Callaway county) and when the Devonian of Canada, extending from Manitoba to the Mackenzie valley, is better known some of our species may be expected in this northern region, if the sea connections were in this direction. Very few of the

2 Bull. Geol. Soc. Amer., vol. 20, p. 545; 1910.

Iowa species have extensive vertical distribution, being limited in most cases to rather narrow zones. In this connection it may be pointed out that of the seven echinoderm genera occurring in the Lime Creek beds only three are found in the underlying Devonian beds. Moreover the geographical extent of most species, as now known, is somewhat restricted.

Of the twenty-two genera only three are wholly limited to the Iowa Devonian; these are *Strobilocystites, Nortonechinus,* and *Devonocidaris.* Nine occur in the Devonian of the neighboring states of Illinois, Wisconsin, Missouri, and Michigan; twelve are found in the New York Devonian;[3] *Stereocrinus* occurs also in Tennessee; six are found in the Kentucky-West Virginia-Ohio region; three are reported from Canada; and eight from Europe. The vertical extent of these genera is interesting in that six of them begin in the Silurian, of which six four lived on to the basal Mississippian; the others arise in the Devonian and seven of these also continue to the Mississippian; eight genera are limited to the Devonian. It may be noted that only six of our genera begin below the Devonian but that eleven or half of them continue to the Mississippian; this fact tends to emphazise a late Devonian age for the Iowa rocks containing the fauna here discussed. In compiling these figues on vertical range *Agelacrinites* has not been considered since the writer is of the opinion that many pre-Devonian species assigned to this genus are generically distinct from those of the Devonian.

The following table, though incomplete, brings out in another way the facts just presented.

3 Fourteenth Rept. Dir. N. Y. State Mus., pp. 47, 48; 1918.

	Iowa	Missouri	Illinois	Wisconsin	Michigan	New York	Tennessee	Kentucky	Ohio	West Virginia	Canada	France	England	Belgium	Russia	Germany	Silurian	Devonian: Lower	Devonian: Middle	Devonian: Upper	Mississippian
Strobilocystites	X																			–	
Agelacrinites	X					X											...	—	—	—	
Nucleocrinus	X			X	X	X		X											—	—	
Codaster	X				X			X									—	—	—	—	—
Melocrinus	X	X		X		X			X		X	X		X		X	—	—	—	—	
Stereocrinus	X						X											—	—	–	
Megistocrinus	X				X	X		X	X										—	—	–
Hexacrinus	X							X					X	X		X			—	—	
Arthracantha	X					X					X									—	
Clidochirus	X					X				X							—	—	—	—	–
Euryocrinus	X				X															—	–
Dactylocrinus	X	X			X									X	X	X			—	—	—
Eutaxocrinus	X					X					X			X		X	—	—	—	—	—
Taxocrinus	X			X		X							X						—	—	—
Synbathocrinus	X				X	X													–	—	—
Deltacrinus	X		X			X										X	—	—	—	—	
Cyathocrinus	X															X	—	—	—	—	–
Poteriocrinus	X					X													—	—	–
Decadocrinus	X					X													—	—	–
Nortonechinus	X																			–	
Xenocidaris	X															X			–	—	
Devonocidaris	X																			–	

Fig. 60. Tab'e showing geographic and stratigraphic distribution of the echinoderm genera occurring in the Iowa Devonian.

The distribution of some of the Devonian genera in Iowa, in the surrounding states, in Canada, and on east into Kentucky and New York has been so well stated in a recent publication by Dr. Frank Springer that the statement is here quoted in full:

> "At Louisville *Dolatocrinus* is the leading genus, followed by *Megistocrinus, Nucleocrinus, Codaster,* etc., but no sign of *Melocrinus* or of any Flexible crinoid; in Callaway County, Missouri, *Melocrinus* occurs, and an Ichthyocrinoid of the genus *Dactylocrinus,* but no *Dolatocrinus* or *Megistocrinus;* in Iowa *Megistocrinus* and *Melocrinus* and a notable new Ichthyocrinoid, but no *Dolatocrinus;* in northern Michigan, *Dolatocrinus, Megistocrinus, Nucleocrinus,* and *Codaster,* of species mostly well differentiated from those of the Louisville area; in Wisconsin, *Melocrinus* closely similar to the Missouri species, forms which also extend far to the north in the McKenzie Basin, Canada; in the last four areas, not including the Canadian, species belonging to the Flexibilia occur, of different forms in each. In western New York and Ontario, *Dolatocrinus* and *Megistocrinus* closely related to the Louisville forms occur; but in addition to these an extraordinary assemblage of the other forms not represented in either of the other areas, which are soon to be described in a Memoir by the New York State Museum."[4]

It is noteworthy that while the Devonian terrane of Iowa extends for some distance into Rock Island county, Illinois, and also northward into the southern tier of counties in Minnesota very meager echinodermal remains have ever been reported from either area. Ekblaw's long list of fossils from the Devonian of the Rock Island region includes none[5] while Doctor Stauffer's lists from the Devonian of Minnesota includes only "crinoid stems."[6] These facts emphasize the rarity of identifiable specimens.

The finding in Iowa of *Arthracantha,* heretofore limited to the vicinity of Lake Erie, of *Dactylocrinus,* a rare but world-wide genus, of the meagerly known Rhenish *Xenocidaris,* and

4 Bull. 115, U. S. Nat. Mus., p. 20, ftn.; 1921.
5 Trans. Ill. Acad. Sci., 1912 (Unpaged reprint).
6 Amer. Jour. Sci., vol. IV, pp. 403, 406; Nov., 1922.

of the genus *Agelacrinites,* are important contributions to the distribution of these genera. Perhaps the most interesting fact in the study of distribution is the presence of certain European genera, especially those of the Rhenish Devonian. In the opinion of the writer further study, especially of the echinoids, will still further emphasize the relationship of our Devonian with that of the Eifel.

Some Significant Facts Brought Out by the Study

Aside from the fact that the study has resulted in a number of new species and in new locality and horizon records for others there are a number of interesting points deserving of brief mention.

The abundance of encrinal limestone and the rarity of complete or identifiable specimens are accentuated by the fact that close to half the species described and illustrated are known only from single specimens or from one specimen and fragments of others. That these are good species there is little doubt in any case but they do illustrate the fact that exceedingly few individuals have escaped falling apart.

The assemblage here elucidated is remarkable for the number of species which have nodose plates or some form of spines or excrescences. Of the six Melocrinids only one has smooth plates, three of the Megistocrinids are nodose, one of them remarkably so, and *Arthracantha* and *Stereocrinus* have their special forms of decoration. The echinoid genera are unique in the matter of spines. *Nortonechinus* and *Xenocidaris* have spines of so abnormal a nature as to suggest their being cidaroid rather than perischoëchinoid genera. In fact the latter genus has been doubtfully included with the cidarids in the second edition of Zittel's Textbook of Paleontology.

The rhomb-bearing cystids of the Iowa Devonian are the latest known species of this order, the group having reached its climax in the Ordovician or Silurian, with a good showing in the Lower Devonian. It is rather surprising that *Strobilocystites* has not been recognized in other parts of our basin as have our equally rare and interesting species of the blastoid, *Nucleocrinus.*

The genera *Melocrinus* and *Megistocrinus* are represented by six and eight species respectively. The latter is by far the most common genus in the area and most of the crinoidal limestone is largely made up of dissociated calyces, arms, and stems of its species.

Hexacrinus, though a common genus in Europe, is rare in America. Up to the writing of this report only two species were known from America and these by but a few specimens. One of the two, *H. occidentalis,* already described from Iowa, is here accompanied by two others bringing the American total to four—three of them from Iowa. The most gratifying fact, however, is that a definite zone bearing *Hexacrinus* plates has been found and traced for several miles. Scores of the plates have been collected and complete calyces may confidently be expected upon closer search.

And finally the most remarkable part of the study is the notable echinoid material found in the Lime Creek beds. Paleozoic echinoderms are rare, especially below the Mississippian. The Ordovician and Silurian have contributed a few while eleven species have previously been obtained from the Devonian. Seven of these, belonging to three different genera, are from the Rhineland, two are from England and two from New York. A tabular arrangement follows:

Eocidaris laevispina (Sandberger)	Germany
Lepidocentrus rhenanus (Beyrich)	Germany
L. mülleri Schultze	Germany
L. eifelianus Müller	Germany
Xenocidaris clavigera Schultze	Germany
X. conifera Schlüter	Germany
X. cylindrica Schultze	Germany
Lepidesthes devonicans Whidborne	England
Pholidocidaris acuaria (Whidborne)	England
Lepidocentrus drydenensis (Vanuxem)	New York
Lepidechinoides ithacensis Olsson	New York

It is regrettable that our echinoid material is dissociated, but the individual plates, spines, and other parts are very well preserved and the material is in places very abundant. The reader may judge for himself as to the interpretation put upon the specimens by the writer, and whether right or wrong an

honest attempt has been made to describe the material as it occurs.

No echinoid remains have been seen in the Cedar Valley beds though close search has been made in certain zones; enough, but very imperfect, material has been found in the Shell Rock limestone, however, to assure us that a few scattered echinoids lived at the time of its deposition. Since writing the greater part of this paper certain plates and spines have been found in the Owen beds, which are the uppermost strata of the Iowa Devonian and at some distance above the zones containing *Nortonechinus* and *Devonocidaris*. In many respects the plates resemble those of *Lepidocentrus* rather than those of *Nortonechinus*. Unfortunately they are so worn as to obscure some of the details necessary for correct generic diagnosis.

The Iowa Devonian

The Iowa Devonian is composed of a body of limestone, dolomitic in places, and shales. These outcrop in a diagonal belt forty to sixty miles wide extending across the state from the middle of the northern boundary to Davenport on the eastern border. They continue for some distance northward into Minnesota where they disappear beneath younger strata, and also southeastward into Rock Island county, Illinois, where again they disappear below younger rocks. The various members of the system dip gently to the southwest; they have been but little disturbed by folding or faulting except in a minor way locally and that has been largely in connection with brecciation which has crushed and distorted the lower terranes over a part of the area.

A complete discussion of the Devonian system, as developed in Iowa, will appear in another paper, now in preparation. The synoptic table given below will serve as a convenient reference in connection with the geological position of the species described in this paper.

Devonian	Upper Devonian	Lime Creek-State Quarry	
		(Break)	
		Cedar Valley	
		Wapsipinicon	Davenport { Upper / Lower } Independence Otis

Fig 61. Table showing divisions of Iowa Devonian.

As shown in the table all the Iowa Devonian is here assigned for the first time to the Upper Devonian. White[7] was of the opinion that it all belongs to one series and influenced by Hall and others, he correlated it with the Hamilton of the Middle Devonian. Later Hall and Whitfield assigned the Lime Creek beds to the Chemung[8] but left the subjacent beds in the Middle Devonian. To the Upper Devonian assignment, Calvin later added the State Quarry beds which also are separated from the Cedar Valley by an erosion interval. The Sweetland Creek beds of Muscatine county are likewise set off by an erosional unconformity from the Cedar Valley. Calvin placed them in the Upper Devonian but there is some doubt about their stratigraphic position since the fossil evidence is indecisive and Kinderhook may well be their final assignment.[9]

Weller[10] in his paper on the "Correlation of the Middle and Upper Devonian and the Mississippian Faunas of North America" placed the Cedar Valley as contemporaneous with the Portage and the Wapsipinicon as the time equivalent of the later Hamilton. The tendency has been to follow this correlation in the main, leaving only a part of the Wapsipinicon in the Middle Devonian. Schuchert in his table has practically followed the above and the Iowa Survey has tentatively ac-

7 Geol. Surv. Iowa, vol. I, p. 187; 1870.

8 Twenty-third Ann. Rept. N. Y. St. Mus., 225, 226; 1873.

9 Weller, Jour. Geol, XVII, pp. 266, 267; 1909. Textbook of Geology, A. W. Grabau, Part II, p. 443, Heath & Co., N. Y., 1921.

10 loc. cit., p. 266.

cepted the usage.[11] The line of separation has been regarded as the horizon of *Hypothyridina cuboides* in the upper part of the Wapsipinicon. Beds below this horizon, such as the Independence shales and the Otis, have been placed in the upper part of the Middle Devonian series. Since the fauna of the Independence shale has certain affinities with that of the Lime Creek and since the chief fossil of the Otis is a species akin to *Martinia subumbona* it impresses the writer that it is more logical to place all the Devonian in one series especially as there is no noticeable stratigraphic break either within or at the close of the Wapsipinicon. The Wapsipinicon-Cedar Valley line is based almost wholly on paleontological grounds, being formerly drawn by Norton just above the *Phillipsastrea* horizon and by Calvin just below this coral bed.[12] The *Spirifer pennatus* beds, too, have been held to be the highest part of the Upper Davenport. At some exposures where the above species are absent a detailed study of the fauna is necessary. As a rule the fine-ribbed *Atrypa reticularis* (*Atrypa independencis* Webster, 1921), *Gypidula comis* (Owen) and some others do not pass up into the basal Cedar Valley. At several outcrops the separation is largely a matter of paleontology although lithology and brecciation aid appreciably in many localities. Recently the situation has been well summarized by Norton.[13]

The Cedar Valley is very variable both lithologically and faunally as it is traced from point to point. Substage names that apply fairly well have been proposed for the strata of Johnson county[14] but these can not be applied along Mississippi river nor in the northern half of the terrane. A glance at a geological map of Iowa will show that the Devonian belt is considerably wider in the northern tiers of counties than in the central or southeastern parts of the state. This is true regardless of the distribution of the Lime Creek stage. Since the general amount of dip is not appreciably different in northern Iowa and since the Wapsipinicon outcrop narrows north-

11 Paleogeography of North America, Bull. G. S. A., vol. 20, p. 541; 1910.
12 Iowa Geol. Surv., vol. ix, p. 452; 1899.
13 Iowa Geol. Surv., vol. xxvii, pp. 362-370; 1921.
14 Iowa Acad. of Sci., vol. xix, pp. 149, 150; 1912.

ward and disappears in Howard county, the combined thickness of the Cedar Valley substages is greater in the northern counties than in the latitude, for example, of Iowa City. The wider distribution in the northern counties is partly explained by the eastward extension of the Cedar Valley until it overlaps the Ordovician.[15] However, in parts of Butler, Floyd, northeastern Cerro Gordo, and counties to the north there come in recognizable formations which are higher and faunally separ-

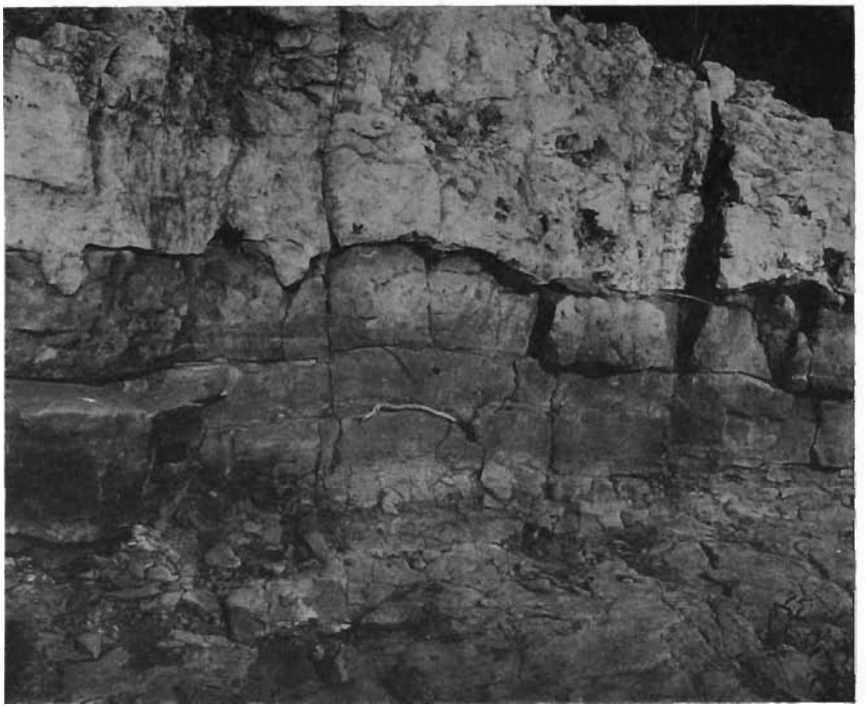

FIG. 62—Contact between the Nora limestone and the Mason City dolomite, left bank of Lime creek, near the north line of section 16, township 95 north, range 18 west. The part of the Nora shown in the figure is the white limestone of the lower *Actinostroma* horizon. The total thickness of the Nora at this point is twenty-two feet; over it lies six or seven feet of the basal blue shale of the Lime Creek stage. (*Photo by Calvin.*)

able from the Cedar Valley. They are not thick, probably not exceeding one hundred feet in vertical extent. The general group of these is called the Shell Rock limestone from their typical development along Shell Rock river between Rockford and Nora Springs and on northward, also about Mason City and

15 Iowa Geol. Surv., vol. xiii, p. 38; 1903.

to the north and northwest. The upper member of this group is the Nora limestone,[16] whose sharp contact with the basal blue shale of the Lime Creek stage may be seen on Lime Creek just west of the town of Rockford. Below the Nora at this point and separated by a slight erosional unconformity is a dolomitic limestone, the Mason City dolomite of Calvin.[17] This formation is well developed in and about Mason City, at Nora Springs, and on south of the latter place along the river. It is suggested that eventually the Shell Rock may be made a stage with the Nora, Mason City, and possibly other horizons as substages. Space does not permit further elaboration here and moreover detailed stratigraphic discussions are outside the scope of this paper.

Acknowledgments

In the preparation of a report of this nature extending over a period of years many persons are solicited in one way or another for suggestions, for specimens, for literature, and for other matters incidental to the problem. It is a pleasure to acknowledge here that without exception everyone has been most ready to comply.

One of the features of this report, as of any similar report, consists of the new species, especially those of more than local interest. So many of the fine and rare species here described have been collected by Mr. C. H. Belanski that it is difficult properly to express the debt this contribution owes him. He is an intelligent and indefatigable collector and a keen observer. He has generously turned over hundreds of fine specimens from northern Iowa to the writer for study. Many of these, including types, have been donated to the paleontological collections at the University. The types of the following species were collected by him: *Melocrinus belanskii, Hexacrinus springeri, Hexacrinus iowensis, Dactylocrinus stellatimbasalis, Nortonechinus welleri, Strobilocystites schucherti,* and he has contributed the cotypes of as many more.

An excellent collection of Johnson county echinoderms was

16 Science, n. s., vol. 37, p. 459; 1913.
17 Geol. Surv. Iowa, vol. VII, p. 144, in table; 1897.

kindly submitted for study by Mr. T. J. Fitzpatrick. The collection is the property of and was collected by Mr. Fitzpatrick and his wife, Mary Frances Linder Fitzpatrick. They were accompanied by the collector's full field notes. One of the specimens in this lot is credited to Mr. Fitzpatrick's father-in-law, Mr. Anton Linder.[18]

The residue of the Barris collection, consisting of several fine blastoids and crinoids, some of them type species, was loaned for study by the Davenport Academy of Science through the kindness of the curator, Prof. J. H. Paarmann.

Mrs. David Brant deserves especial mention for contributing to the study an instructive lot of beautiful specimens of *Megistocrinus clarkei* collected at Waterloo.

To Doctor W. H. Norton the writer is especially indebted for the first lot of echinoid spines and plates from the Lime Creek beds and for other specimens as well as for many valuable notes and suggestions drawn from his rich field experience in the Iowa Devonian.

For still other specimens the writer has to thank his students who have at all times enthusiastically contributed from their collections. Individual mention is made under the appropriate species.

Especial thanks are due several individuals who have helped in other ways. To Doctor Frank Springer much is due. He kindly aided in the identification of several species, he contributed literature and prints, and his words of encouragement have been greatly appreciated. Doctor Robert Tracy Jackson has been helpful, and his opinions on some of the echinoid remains aided materially. Doctor F. A. Bather, of the British Museum, has kindly furnished indispensable literature. Professor Stuart Weller has offered much valuable counsel and has carefully examined some of the specimens.

Doctor Otto T. Walter has made many of the drawings and has aided in cleaning and cataloging the material. Mr. Merrill A. Stainbrook has been of much help in the photographic work.

[18] Since the above was written Mr. Linder has passed away in his one hundred and first year.

He has also collected several fine specimens, some of them new species.

To his colleagues in the department and to the officers of the State Geological Survey the author is especially grateful for many valuable suggestions and for their hearty coöperation.

Description of the Genera and Species.

CYSTOIDEA von Buch
RHOMBIFERA Zittel
CALLOCYSTIDAE Bernard

STROBILOCYSTITES White
= STROBILOCYSTIS Bather

Calyx ovoid or subspherical, with eighteen plates in four cycles. Ambulacra four, which may or may not give off secondary branches. Pectinirhombs three, their halves separated, and situated on plates 1 and 5, 14 and 15, and 12 and 18, one rhomb on each of the four parts of the calyx as defined by the ambulacra except on the posterior part; rhombs of the right and left parts are above the middle of the calyx, that of the anterior part near the base; the long diagonal of the left rhomb is nearly at right angles to the vertical axis of the calyx, that of the right nearly parallel to it, and that of the anterior rhomb obliquely transverse. Anal pyramid situated adorally on the posterior and narrowest quadrant and composed of six pieces and an outer circle of nine pieces. A double madreporite and minute hydropore on plate 23. Column stout, tapering.

Genus callocystine in character and fairly close to Hall's *Sphaerocystites* there being some telescoping of the second and third cycles, but plate 12 is not in contact with plate 2 as is the case in some species at least of that genus. *Strobilocystites* is limited to the Iowa Devonian so far as is now known.

STROBILOCYSTITES CALVINI White
Plate XXXV, figs. 1-11, 13, 18.

1876. *Strobilocystites calvini* White. Proc. Acad. Nat. Sci. Philadelphia, vol. 28, p. 28.

1883. *Strobilocystites calvini* Calvin. History of Johnson County, Iowa, Notes on the fossils, pp. 558, 560.

Body globular to ovoid or depressed. Ambulacra four, branching irregularly, the number of branches being from two to seven on each ambulacrum—those on either side of the anal pore tending to have the fewest number; ambulacra and branches are set into broad depressions in the theca and they cover most of the surface between and around the anus and pectinirhombs thus obscuring the suture lines between the thecal plates; the main trunk of each ambulacrum reaches quite to the base; ambulacral plates alternating, slightly elevated, each bearing a brachiole facet which facets are from one to three millimeters apart, ambulacral groove zigzag, narrow, and deep.; covering plates or ambulacralia and brachioles are lost.

Pectinirhombs three, their two parts wholly separated by a suture line, each half deep set and limited by a sharp bounding ridge and containing from twenty-four to thirty-two dichopores; on some weathered specimens the connecting ducts which extend within the plates from the dichopores to the line of suture are exposed.

Anal pyramid low, made up of a rosette of six small pieces encircled by two or three large aboral and six or seven smaller plates. Madreporite situated on plate 23, and composed of two oval, subequal areas with concave surfaces and each surrounded by a sharply raised rim; hydropore small, situated betweeen distal ends of the madreporite areas, its pyramid not observed.

Surfaces of thecal plates where not obscured by the ambulacra are marked by a maze of low papillose nodes and discontinuous ridges.

Stem opening large, round or rounded-oval, the part in the plates countersunk and "having no articulating striae." (Troost, Bull. 64, U. S. N. M., p. 9.) Stem round, tapering, and slightly curved; the lumen large; segments appear to be telescoped one within the other, their peripheries angular.

The better of the two specimens available to White is the type on which he based his generic and specific descriptions. It

was collected by Doctor Calvin near Iowa City[19]. The other specimen is considerably damaged by exfoliation and the base is broken off. It is a little larger than the type. Since that time fifteen or twenty additional specimens have been collected in the state. The majority of these, too, average considerably larger than White's type.

Position and localities.—The Iowa City specimens, so far as is known, have been found at the Sanders quarry, on the left bank of Iowa river on the "Dubuque road" near the north limits of the city at a level about fifteen to twenty feet above the ordinary stage of the river. They occur in a tough gray crystalline limestone which weathers to a friable yellowish-brown rock; the zone is approximately ten feet below the Idiostroma ledge seen near the top of the quarry at the south end. Plates of this species associated with a specimen of *Megistocrinus latus* have been found on slabs in the sides of a small creek in northwest quarter section 8, in Penn township about a mile northeast of North Liberty; the presence of *M. latus* suggests a lower horizon than at the Sanders quarry. In 1915, Mr. J. V. Howell found a specimen and some dissociated plates on a loose slab at Aicher's quarry in section 27, township 80 north, range 6 west. One specimen at hand was collected some years ago by Mr. E. P. Whipple from Devonian outcrops about Vinton, the exact locality now unknown. One quite large but crushed specimen was collected along Lime creek, a tributary of Cedar river, in Buchanan county, by Mr. Merrill A. Stainbrook. The writer has since found two others there as well as a number of dissociated plates and a stem.

Two fine calyces in the Fitzpatrick collection are from Sanders quarry. One of them preserves eleven millimeters of a gently tapering and curved stem. The other is larger and displays a perfectly preserved anal pyramid, see drawing on Plate XXXV. A portion of the stem, freed from the calyx at the time it was collected, accompanies this specimen also.

A nearly perfect but slightly distorted calyx, also from the Sanders quarry, is in the Cornell College Museum. It was collected by one of Doctor Norton's pupils.

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19 Amer. Jour. Sci., Vol. XXV, p. 434, 1883.

In some earthy dolomitic beds in the Shell Rock limestone in the vicinity of Nora Springs in Floyd county occur abundant internal molds of a *Strobilocystites* presumably of this species; a few of them show interesting molds of the pectinirhombs. Webster[20] reported this species from near Nora Springs nearly thirty years ago.

STROBILOCYSTITES POLLEYI Calvin.
Plate XXXV, figs. 14-17.

1883. *Strobilocystites polleyi* Calvin. History of Johnson County, Iowa, Notes on the fossils, pp. 558, 560.

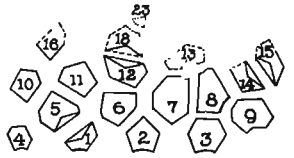

FIG. 63—Analysis of *Strobilocystites polleyi* Calvin. Plates of upper cycle in part restored.

Species based on a single specimen, the oral end of which has been broken off and from which, too, the ambulacral plates have been exfoliated. Calvin says:

> "The *S. polleyi* differs from it (*S. calvini*) in being larger, more globose, and in having the surface ornamented with minute irregular, vermicular furrows instead of the papillae that characterize the *S. calvini*. The arm-grooves of *S. polleyi* do not reach more than half way to the base."

The ambulacra, however, do reach quite to the basal circlet of plates and each is branched although the full extent of the branching is uncertain. No ambulacrum or branch invades those parts of plates 1 or 6 immediately to the right of the basal pectinirhomb as is the case in all specimens of *S. calvini* at hand. In fact the greater part of the surface of the theca is uninvaded and this together with the loss of the ambulacral plates makes it easy to trace the sutures and to make an analysis of the calyx plates.

The type was collected in the "Devonian beds of Cedar county," presumably by Mr. J. F. Polley who graduated in the engineering course at the University of Iowa in 1876 and for whom Calvin named the species. The specimen was a part of the Iowa geological exhibit at the Centennial Exposition at

20 Webster, C. L., Davenport Acad. Sci., vol. V, pp. 104, 107; 1893.

New Orleans in 1885; the display label still accompanies the specimen. The only Devonian outcrops in Cedar county likely to have yielded fossils are the exposures and quarries in sections 26, 35, and 36, township 79 north, range 3 west. These are across the county line just north of Atalissa, Muscatine county[21]. It is known that Professor Calvin and his classes frequently visited these localities in the seventies and eighties and that small quarries were in operation about this time. The horizon is the upper part of the Wapsipinicon beds with some basal Cedar Valley at the top. It is uncertain at what level the type specimen was found; at any rate the horizon of the Atalissa quarries is considerably lower than that of *S. calvini* in Johnson county to the west.

Strobilocystites schucherti n. s.
Plate XXXV, figs. 12, 19-21.

Calyx elongate, ovoid, somewhat quadrate in cross section. Ambulacra extending to the base; in the three specimens at hand, one, number 3506, shows no branching, another, number 3505, has one prominent branch on the left anterior ambulacrum, and a third, number 3507, which is imperfect, has two short branches, one with a single ambulacral plate and another with two plates. Both branches are high up and on the same arm as in number 3505. Ambulacral plates are nodose and prominently elevated; brachiole facets seven to nine in ten millimeters on either side of the ambulacrum.

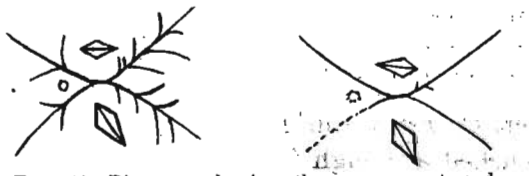

Fig. 64—Diagrams showing the arrangement and number of ambulacral branches in *Strobilocystites calvini* and the almost complete absence of branches in *Strobilocystites schucherti*.

Pectinirhombs are situated as in *S. calvini* but have fewer dichopores, there being from twelve to eighteen in each half on numbers 3505 and 3506. Moreover each half rhomb is curved or bow-shoped on these two. On number 3507 the rhombs are much as on *S. calvini*.

Madreporite small, double, the anterior area elongate and

21 Iowa Geol. Surv., vol. XI, p. 341; 1901.

larger, the other round, both surrounded by a crater-like rim; hydropore in depressed area between the madreporites, round and but slightly smaller than the posterior madreporite.

Thecal plates smooth or nearly so in the interambulacral areas, suture lines fairly distinct. Stem opening as in previous species.

Position and localities.—Specimen 3507 from lower part of Cedar Valley beds one and one-half miles west of Solon; collected by Mr. L. P. Elliott, a former student of Professor Calvin's and an enthusiastic collector of local fossils.

Specimens 3505 and 3506 were collected by C. H. Belanski in the Shell Rock limestone in the Belanski quarry at Nora Springs, Iowa; this is approximately the zone of *Hexacrinus springeri.*

These two specimens are made the types. It is to be noted that they occur at a considerably higher horizon than number 3507 from near Solon. The latter may eventually be set off in another species when more material from this horizon is obtained. However, except for the shape of the rhombs and a few minor details, it is much like the other two.

The reduction of ambulacral branches in this species appears to be one of the indications of the extreme specialization attained by the genus before the disappearance of the rhomb bearing cystids of which it is one of the last, if not the last, representative.

The specific name is given in honor of Professor Charles Schuchert and in appreciation of his excellent papers on the Cystidea of the Lower Devonian of Maryland and West Virginia.

EDRIOASTEROIDEA Billings
AGELACRINIDAE Hall.

AGELACRINITES HANOVERI n. s.
Plate XLVI, figs. 1-5.

Body compressed, circular, sessile, and permanently attached; oral surface somewhat depressed and bounded by a steep peripheral wall.

Thecal plates strongly imbricate, their inner edges curved adorally and their surfaces smooth. Marginal plates of the inner wall elongate, wider than those of the interambulacra and apparently in two alternating rows; those of the inner row a little the smaller. Outer wall made up of very numerous minute thin plates.

Rays five, two solar and three contrasolar. The two solar rays are the right anterior (IV) and the right posterior (V). The cover plates comprise two rows of alternating triangular pieces with apices of the triangles interlocking and directed toward the median line of the ray. Anal pyramid centrally located in the area between I and V.

Dimensions: specimen 3523a has a maximum diameter of 34 millimeters; 3521 is 20 millimeters, and 3522 is 8.5 millimeters in diameter.

Specimens found attached to colonies of a compact multilamellar Stromatopora. They have suffered from wear and weather to such an extent that no one specimen shows all the characters and none of them shows the oral plates or the details of the anal pyramid.

It may be noted that this is the first agelacrinite found with two solar rays since Vanuxem described and illustrated *Agelacrinites hamiltonensis* from the Hamilton of New York[22]. From this species ours differs chiefly in having imbricating and unsculptured interambulacral plates. Vanuxem's species has been made the genotype. Since then the genus (also spelled *Agelacrinus*) has been extended to include many species from the Ordovician to the Mississippian. Most of the described forms differ from the genotype, it would seem, by more than specific characters. Strictly interpreted *Agelacrinites* is limited to those forms whose "thecal plates are mosaic, irregular, and sculptured; which have very long and narrow rays and a peripheral band composed of large plates with very small ones at the margin[23]. Meek and Worthen erected a genus, *Lepidodiscus*[24], to include species with "squamous thecal plates,

22 Geol. Third Dist. New York, pp. 158, 306, fig. 80; 1842.
23 After J. M. Clarke, Bull. 49, New York State Mus., p. 193; 1901.
24 Geol. Surv. Illinois, V, p. 513; 1873.

very long narrow rays, and whose peripheral band is very narrow or extinguished and composed of large and small plates; the latter few and projecting on the aboral surface.''[25] Other genera and subgenera occur to those familiar with the literature and a revision of the Ordovician agelacrinids is in progress[26]. It appears that *A. hanoveri* partakes of some of the characters of *Agelacrinites* and of *Lepidodiscus* as set forth by Clarke in the quotations given above. A new genus may be necessary for its reception eventually.

Specific name given for Mr. Hanover H. Belanski, who collected the type specimens and donated them to the University museum.

Position and locality.—In Stromatopora reef of the Shell Rock limestone, near Mason City, Iowa.

AGELACRINITES sp.
Plate XLVI, fig. 6.

Description based on an imperfect specimen which preserves very well the marginal plates of the peripheral wall; the plates of the outer ring are small and fine, those of the inner are coarser, alternating, and nearly vertical in position.

The thecal plates and those of the rays are jumbled together in such a way that the turning of the rays can not be determined. On one part of the surface the thecal plates can be seen to imbricate over a small area. The specimen, which is nearly circular, is 20.8 mm. in diameter and the wall is between two and three mm. in height.

Specimen attached to the brachial valve of a coarse-ribbed individual of *Atrypa reticularis* L.

Occurrence.—Cedar Valley limestone; in the coarse-ribbed Atrypa zone, along Lime creek, east of the cemetery, Brandon, Iowa. Collected by Merrill A. Stainbrook.

BLASTOIDEA Say

This extinct class, limited to the Paleozoic, is represented in the Iowa Devonian by one doubtful *Codaster* and by three fine

25 Loc. cit.
26 Bull. Lab. Denison Univ., vol. XVII, p. 400, 1914; also vol. XVIII; 1917.

species of *Nucleocrinus*. The Iowa species are closely akin to those of northern Michigan and of the Milwaukee area but quite different on the whole from those of the Onondagan of the Falls of the Ohio region, a representative of which is the well known *N. verneuili* (Troost). Three species are described herein. However, in Barris' lists[27] an additional species *Elaeacrinus elegans* Hall, is given as one of the rarer forms from the outcrops along the river below Davenport. In the absence of the material which Barris had at hand it is thought that his *N. elegans* was probably a misleading specimen of *N. obovatus*. At the end of his list he cites a number of genera containing undetermined species, among them *Elaeacrinus,* and the unidentified forms doubtless belong to one or more of the Davenport species which are discussed below.

Prof. U. A. Hauber of St. Ambrose College, Davenport, has submitted to the writer a tray of thin slabs from the horizon of *Cystodictya hamiltonensis* below that place and along the river. The slabs contain fragments and crushed specimens of a *Nucleocrinus*. Though their markings suggest *N. obovatus* specific determination can not be made with certainty.

EUBLASTOIDEA Bather

CODASTERIDAE Etheridge and Carpenter

CODASTER SUBTRUNCATUS (Hall).

Plate XXXVI, fig. 15.

1858. *Pentremites subtruncatus* Hall. Geol. Iowa, vol. I, pt. ii, p. 485, pl. I, fig. 4.

1882. *Troostocrinus subtruncatus* Etheridge and Carpenter. Ann. & Mag. Nat. Hist. vol. IX, p. 249 (in a list).

1886. *Codaster subtruncatus* Etheridge and Carpenter. Cat. of the Blastoidea of the Brit. Mus., pp. 132, 265 (in a list).

1903. *Codaster subtruncatus* Hambach. Trans. Acad. Sci. St. Louis, vol. XIII, p. 48.

"Turbinate or reversed pyramidal, the base round, gradually becoming angular above, distinctly pentangular at the base of the pseudambulacral spaces; base

[27] Proc. Davenport Acad. Sci., vol. VII, pp. 25-27; 1889.

small, almost pointed, apex broad subtruncate above; basal plates small, less than half the length of the body; radial plates less than one and a half as long as the basal plates, slightly divided above for the reception of the pseudambulacral plates; interradial plates small, rising above the centre when complete; summit convex, flattened in the centre; pseudambulacral spaces short, abruptly convex in the middle; poral plates fifteen or more in each series; ovarian apertures small, round."—After Hall, who employed Roemer's terminology.

This unique specimen was obtained by Hall from the shaly limestones of Cedar Valley age in the vicinity of Buffalo (formerly called New Buffalo), Muscatine county, Iowa. The whereabouts of the type is unknown to the writer. Barris[28] thought this species might be identical with *Heteroschisma gracile* Wachsmuth—and judging from Hall's figure there is a strong resemblance. The fact that Barris years afterward listed[29] *H. gracile* among the fossils from the vicinity of Davenport may have been based only on this supposition. In support of this probable conviction on part of Barris, there is in the University of Iowa a lot of *Codaster gracilis* (=*H. gracile*) from Alpena, Michigan, which Calvin secured from Barris; a label accompanying them in Barris' handwriting reads "*Heteroschisma gracilis* Wachsmuth", and "*Pentremites subtruncatus* Hall" is written below as a synonym.

Two views of a specimen of *Codaster gracilis* from Michigan are given for comparison on plate XXXVI, figures 13, 14.

NUCLEOCRINIDAE Bather

NUCLEOCRINUS OBOVATUS (Barris).

Plate XXXVI, figs. 6-9, 16, 17.

1883. *Elaeacrinus obovatus* Barris. Geol. Illinois, vol. VII, p. 358, text fig. 3.

1886. *Elaeacrinus obovatus* Barris. Proc. Davenport Acad. Sci., vol. 4. p. 88, Pl. i, figs. 1, 2, and text fig. 3.

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28 Geol. Illinois, vol. VII, p. 357; 1883; Davenport Acad. Sci., vol. 4, p. 87; 1886.

29 Davenport Acad. Sci., vol. 7, p. 27; 1899.

1886. *Elaeacrinus obovatus* Etheridge and Carpenter. Cat. of Blastoidea in Brit. Mus. p. 216 (in a list).

1903. *Olivanites obovatus* Hambach. Trans. Acad. Sci. St. Louis, vol. XIII, p. 50 (in a list).

1911. *Nucleocrinus obovatus* Cleland. Wisconsin Geol. Surv. Bull. XXI, p. 43, Pl. 3, fig. 2.

"Body obovate or elongate-balloon shaped, more than once and a half as long as wide; upper half wider than the lower, semi-ovoid; greatest width at about two-thirds from the base; lower half gradually increasing in width to the distal end of the ambulacra; base truncate with a deep concavity, which is filled by the column. Cross-section pentangular, with straight or very slightly convex sides, except along the basals, where the sides are somewhat concave, and the section more stellate.

Basals deeply imbedded within the columnar cavity, the outer angles barely reaching the margin. Radials comparatively small; length twice their width at the basiradial suture, gradually increasing upward, so that the forks or limbs at their upper side are about equal in width to the body of the plate at its lower side. The lateral sides are somewhat thickened at the upper face of the edge, more particularly toward the lower end of the plate, where they produce indistinct ridges at the suture lines. The upper side of the limbs is gracefully curved in an upward direction, with reëntering angles toward the lateral sutures, and deeper ones toward the radial sinuses. From the bottom of the plate there extends to the radial sinus (which, in this species, is about half-way to the top of the limbs) a conspicuous rounded ridge, ending in a very prominent lip; and it is this structure mainly which produces the truncation toward the basal region, which otherwise would not be very perceptible.

Interradial or deltoid pieces large, measuring almost four-fifths the length of the body; broad lanceolate. Four of these have a length equal to twice their greatest width. The fifth, that of the posterior side, which in this genus is divided throughout its full length by a large anal plate, occupies, including the latter piece, no greater width than the four regular interradials, and the two halves are narrower at any

place than the interposed anal plate. The latter is lanceolate, of nearly equal width throughout, slightly tapering at the upper end. Its lower side rests on the same surface with the other plate, but gradually rises above the general level, and at the top is highly elevated, standing out conspicuously over the adjoining parts. Even in height it extends beyond the limits of the other parts of the body.

Anal aperture large, oval in form, horizontal in position. Toward the outer side, the opening is formed by the wall of the anal plate, which at the upper end is bulging outward without being excavated. The lateral sides of the aperture are formed by the upper curved ends of the interradials, which are connected by two or three small anal vault-pieces, and these constitute the upper boundary of the aperture.

Ambulacra long, narrow, linear, raised above the general level of the body, except close to the oral pole, near which they curve abruptly toward the oral opening, and the ambulacrum becomes located below the abutting surface. The lancet-piece is deeply grooved along the median line, and when the side-pieces (pore-pieces of Roemer) are not in place, there is at the suture, along each side of the plate, a deep sulcus, penetrated by the hydrospire-pores. This sulcus, however, when the side-pieces are *in situ,* is totally filled, and the sides of the ambulacrum rise abruptly above the abutting edges. The side-pieces rest against the upper face of the deeply crenulated ridges of the lancet-piece. They are strongly wedge-shaped and placed obliquely to the ambulacral or food groove, with the smaller angle directed to the aboral side. Their number is from about sixty to nearly ninety in very large specimens. The outer side-pieces (supplementary pore-pieces of Roemer) are comparatively large, their longer side being about two-thirds, their shorter sides fully one-half, of the corresponding sides in the pore pieces.

The summit is a flat disc, somewhat depressed in the middle, sub-pentangular in outline, the angles resting against the slightly truncated upper part of the oral plates, leaving in the direction of each ambulacrum a good sized passage. The central aperture is pentangular, rather deeply depressed.

Spiracles ten, one to each side of the ambulacrum; those of the posterior side not in contact with the anal aperture. They are in this species not easily detected, being placed laterally within the projecting edges of the interradials, which for their reception are at this place more prominent, and somewhat excavated. The hydrospires are arranged in ten groups, with two in each group; they are in form similar to those of *Granatocrinus Norwoodi,* but comparatively a little larger. Hydrospire-pores small, and more or less hidden.

Column of medium size, round, composed at the upper end of high joints.

The ornamentation of the radials consists of indistinct concentric curves sub-parallel with the arched upper surface of the plate. The ornamentation of the interradials, as in most species of *Elaeacrinus,* is sharply divided by two longitudinal lines, the median part (which in position and somewhat in form, at the four lateral sides of the body, corresponds to the large anal plate of the posterior side) is more or less destitute of ornament. The two sides, however, are crowded with rows of small granules, arranged so as to divide the field into narrow parallel spaces, which are transversely arranged, and of the width of the pore-pieces."—After Barris.

In writing the above description, Barris made use of specimens of various sizes, some from Iowa and some from Michigan. He says, "the largest measuring one inch and three-quarters in length, the smallest seven-eighths of an inch." His figure 1, on plate I, is of a specimen fully two and three-eighths inches long. This specimen is now in the Davenport Academy collection and is labelled "Type specimen of *Elaeacrinus obovatus.*" Unfortunately no locality record is given hence we do not know whether this fine specimen is from Iowa or from Michigan. The fact that it is at least five-eighths of an inch longer than the longest which Barris says he used in writing his descriptions leads us to suspect that his figure 1 was entered on the plate after his manuscript had been set up and that the specimen was not at hand when he wrote the de-

scription of the species. In other respects than size it conforms quite closely to the description of the types.

Position and localities.—Barris' type specimens are from the *"Spirifer pennatus"* beds of the Cedar Valley stage, near Buffalo, Iowa; from the Cedar Valley near Iowa City; and "from the top of the Hamilton group in the Thunder Bay region of northern Michigan." The most notable locality near Buffalo is west of the village in Barris' "Fifth Ravine" along the valley of Cedar Creek. The small local quarry, which Norton calls Clarke's quarry, has of late years been expanded on a large scale by the Dolese Brothers.

A badly crushed specimen in the Davenport Academy collection is at least 45 millimeters in length. It is tentatively referred to this species.

In Owen's 1852 Report on the Geology of Wisconsin, Iowa, and Minnesota, pages 508 and 625, he mentions finding a specimen of *Olivanites verneuili* at the mouth of the second creek below Rockingham. This village no longer exists but on a map of Iowa dated 1839[30] it is shown on the right bank of Mississippi river opposite the mouth of Rock river, Illinois, and thus not far upstream from Barris' localities for *N. obovatus.* The specimen collected by Owen presumably belonged to the latter species and not to the Onondagan *N. verneuili,* which differs quite markedly from any of our Iowa species.

One specimen in the University collection was found by Mr. Frank Bond in the Cedar Valley limestone between the wagon road and the river and only a few feet above the level of the water a little south of the old Sanders quarry near the north limits of Iowa City. It is not known where Barris found his Iowa City specimens but it is presumed to have been at this horizon.

A slab from Aicher's quarry, in the University collection, bears a small radial or forked plate presumably belonging to this species. It is faintly marked by fine lines which run parallel to its lateral edges. On the slab is also a specimen of *Strobilocystites calvini.*

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30 Map of Surveyed Part of Iowa (18 counties), New York, 1839, published by J. H. Colton.

An incomplete deltoid plate of ellipsoidal shape and of large dimensions was collected some years ago by Dr. E. J. Cable near the base of the Cedar Valley limestone at Littleton, Iowa. The plate preserves the markings unusually well, the median tract is narrow and slightly raised above its surroundings and its surface is subplane or gently concave. The chocolate brown color of the specimen is in striking contrast with the yellowish gray matrix. Length 47 millimeters, greatest width 26 millimeters; the width is thus fully one-third greater than that of any other *Nucleocrinus* at hand. The specimen is number 450, Museum Natural History, Iowa State Teachers College. (See text figure 65.)

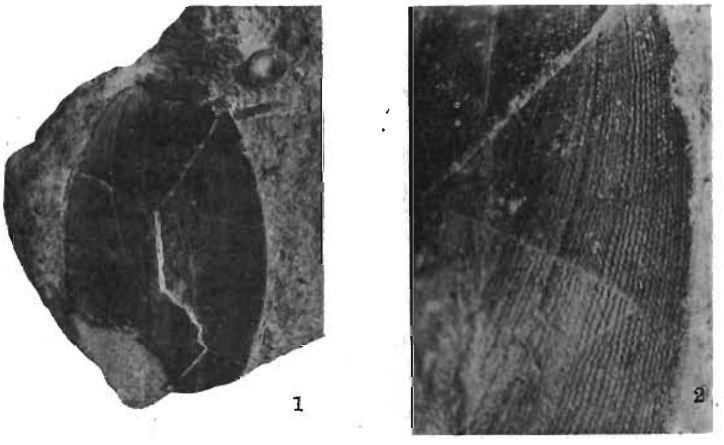

FIG. 65.—Deltoid plate of *Nucleocrinus obovatus* Barris. 1. Natural size, proximal end broken away. 2. Part of surface enlarged about x3, showing the ornamentation. Collected near Littleton, Iowa, by Doctor E. J. Cable.

Three specimens in the collection at the University are from Partridge Point, near Alpena, Michigan, where they were collected by Barris. They have the narrow elongate shape characteristic of this species.

NUCLEOCRINUS MELONIFORMIS (Barris).
Plate XXXVI, figs. 10, 11.

1883. *Elaeacrinus meloniformis* Barris. Geol. Surv. Illinois, vol. VII, p. 361.

1886. *Elaeacrinus meloniformis* Barris. Proc. Davenport Acad. Sci., vol. IV, p. 91, Pl. 1, fig. 3.

1886. *Elaeacrinus meloniformis* Etheridge and Carpenter. Cat. of Blastoidea in Brit. Mus., p. 216 (in a list).

1903. *Olivanites meloniformis* Hambach. Trans. Acad. Sci. St. Louis, vol. XIII, p. 50 (in a list).

"Body small, ovoid, height nearly one-half more than the width; greatest width through the median part, or a little above; curvature toward the two poles nearly equal, but the pole itself at the abactinal side abruptly depressed, and the concavity perfectly filled by the column. Surface of the ambulacra raised but little above the general plane of the body. The plates along the sides of the ambulacra are marked with obscure transverse grooves, bordered at each side by a sharp ridge, which forms along the median portions of the plate a deltoid-like figure. The ridges which join with one end at the summit, with the other at the radial lips, form together around the body a well-marked penta-petaloid figure, in which the ambulacra are placed along the median line; and as the ridges in this species happen to be more conspicuous than the margins of the ambulacra, the ridges appear as the boundaries of the latter. Cross-section along the upper half of the body obscurely decagonal, almost circular, decidedly pentagonal across the lips of the radials.

Basals small, entirely hidden within the columnar cavity.

Radials small, body-part longer than usual in this genus, their lower portions resting within the concavity, whence they bend abruptly in an opposite direction, forming a sharp edge at the end of the body. Length more than twice the width at the basi-radial suture, which is about equal to the width of a limb at its upper side. Sinus very short, enclosing but little more than the lip, which is strongly protruding, and from which a very prominent rounded ridge proceeds to the lower edge of the plate. The upper sides of the limbs are convex, with a reëntering angle above the lateral sutures.

Interradials large, occupying four-fifths of the length of the entire body, divided by two raised lines

into three parts, the inner or deltoid part provided with fine granules, the outer part with transverse grooves, which are equal to the number of side-plates in the ambulacra. The anal plate, which divides the posterior interradial, differs in form but little from the deltoid-shaped portions of the other four interradials; it is, however, a little wider, and at the upper end protruding outward. The anal aperture is large, rhomboidal, the opening in an upward direction. It is bordered toward the peristome by two summit plates, which rest against the upper ends of the two sections of the interradial.

Ambulacra linear, comparatively shorter and probably wider than in any other species of *Elaeacrinus;* lancet-piece exposed within the food-groove, but only at the upper end of the plate, its lower half is perfectly covered by the side-plates. There are 36 to 38 side-pieces (outer side-pieces cannot be distinguished in the specimens), with a deep socket to each plate. The hydrospire-pores are only seen when the side-plates are broken away.

Spiracles ten, one to each side of the ambulacrum; slit-shaped, placed, like those of the preceding species, within the projecting lateral edges of the interradials: those of the anal side non-confluent with the anal aperture. The hydrospires are unknown.

The summit (which in both type specimens has been preserved) is composed of but few comparatively thick pieces, which are similarly arranged as in *Elaeacrinus obovatus.* Column round, central perforation very small."—After Barris.

This species is quite distinct from *N. obovatus* in being shorter and proportionally wider, in having the central area of each interambulacrum definitely set off by a sharp ridge on each side, and in having much less prominent ambulacra.

No specimens from Iowa have been seen by the writer but one from Waterfowl Bay, northern Michigan, is at hand, evidently collected by Barris; accompanying the specimen is a note by Barris which says "I presume I made a mistake, I described it as *Elaeacrinus meloniformis* when it is Conrad's *Nucleocrinus elegans.*" Barris' original position that it differs from *N. elegans* "in the more elongate form, in the mode

of ornamentation, in having almost straight in place of concave interradial sides, and in less protruding and comparatively shorter ambulacra'' has been generally accepted and in the absence of a series of specimens for comparison *N. meloniformis* is allowed to stand.

Position and localities.—From the shaly limestones of Cedar Valley age in the ''Fifth Ravine'' near Buffalo, Iowa, and from the ''Hamilton group'' at Waterfowl Bay and Thunder Bay, northern Michigan. It has not been reported from the vicinity of Iowa City.

NUCLEOCRINUS BONDI n. s.
Plate XXXVI, figs. 2-5, 12, 18.

Body elongate or balloon-shaped, broadly ovate in longitudinal section, widest just above the middle, sharply stellate in cross section; base truncate and deeply excavate; maximum width about three-fourths the height.

Basals deeply hidden within the columnar cavity. Radials small and short, limbs narrow and rounded distally; from the rim of the basal excavation a strong medial ridge extends outward and downward on each plate forming a lip to receive the distal end of the ambulacrum.

The interradials or deltoids are very large and make up the greater part of the theca; each is composed of three areas, a median lanceolate area and two curved doubly-tapering areas, one on either side separating the narrow median area from the ambulacra. The median tract begins at the reëntrant angle between the distal ends of the radials and terminates in an inwardly bent point at the oral pole with the exception of that in the posterior area. In this interradius the median tract is a separate plate. Its upper extremity protrudes above the oral region and for a short distance below the summit its surface is raised slightly above the areas on its flanks; from this region downward, however, its surface is depressed below that of the side pieces. In each of the other four interradial areas the median tract is likewise depressed throughout its length and its sides are limited by low ridges; in the posterior area the lines limiting the anal plate are on the floor of the sunken area end-

ing below at the crests of the radial limbs; between each of these lines and the transversely decorated portion of the side pieces is a very narrow area which vanishes toward the summit; these two narrow tracts are parts of the surfaces of the side pieces.

Anal opening oval, directed toward the summit depression, its outward border formed by the protruding end of the anal plate and its sides enclosed by the inward and downward curving ends of the interradials and by two or three small dome pieces.

Ambulacra very long, narrow, and elevated on sharp keel-like ridges. At the oral pole they curve abruptly downward passing below the roof plates. Aborally they extend a little beyond the base. Lancet-piece sharply and deeply grooved, and partly exposed. Side-plates small, about 120 on each side in the type specimen. When these are removed a series of transverse grooves are seen on the vertical sides of the lancet-piece at the base of each of which is a hydrospire-pore. When the side-plates are in place, these latter features are covered. No distinction between side-plates and outer side-plates can be made out on the specimens at hand. Summit pentangular, covering plates wanting. Spiracles slitlike, ten in number, one on each side of each ambulacrum, and partly concealed under the proximal ends of the interambulacra; those of the posterior side separated from the anal orifice. Column round and small, not filling the basal cavity.

Ornamentation of the radials as in *N. obovatus*. The interradials bear distinctly different ornamentation on the median tract than on the lateral tracts. On the median tract are curved lines which are parallel to the tops of the radials and which may represent growth stages in the history of the theca. In places the lines are replaced by rows of granules; on a few of the areas are one or more fine longitudinal lines. On the laterals are lines which rise along the ambulacral margin and pass in a curved diagonal path to the edge of the median tract, their inner ends being successively higher and higher along the edge of the inner tract from base to summit. These lines too, seem to represent growth periods in the theca; across these,

and directed slightly downward, run lines—one for each pore piece; the whole is arranged so as to produce a graceful cross-hatched pattern on a more or less granular surface.

This species is near to *N. obovatus* with which it is associated in the vicinity of Iowa City. It differs from that species in its greater width and stellate cross section, in the sharply elevated and basally protruding ambulacra, in the consistently sunken median areas of the deltoids, and in the general ornamentation.

This species is close, too, to *N. angularis* (Lyon) from the Devonian of the Falls of the Ohio region of Kentucky and Indiana. *N. bondi,* however, is considerably larger, its deltoid plates are concave throughout their length—not "flattened towards the summit" as in *N. angularis,* described by Etheridge and Carpenter (p. 219), its median tract is more depressed, its ambulacra are narrower and more sharply raised, and as near as can be made out the surface markings are different.

Length of type specimen 39 mm., greatest width 28 mm., length of anterior ambulacrum along its curvature, 48.2 mm., antero-posterior diameter of basal cavity, 5 mm.

Remarks:—A recent communication from Mr. Bond tells of finding of the type specimen and of the joy which Professor Calvin expressed at the discovery. A few weeks later his pupil found a second specimen—the *N. obovatus* mentioned above. Both were given to Professor Calvin who sent them for identification to Mr. Charles Wachsmuth at Burlington. By rare good fortune Mr. Wachsmuth's hand-written note of reply, quoted below, was folded by Calvin and placed beneath the label in the tray which contains the type specimen. It bears no date:

"It is possible that these two specimens belong to different species, the larger differs considerably by its angularity and in the proportions of the interambulacral spaces, in which it resembles *Nucleocrinus angularis* Lyon. The smaller one is in my opinion certainly of new species, and identical with some of the specimens of this genus found at New Buffalo, Iowa, and in the Lake Superior region. Of both localities I have here for

comparison a large number of fine specimens, some of them nearly 3 inches long, others smaller. Their width in all of them is scarcely one-half their length, and they all have straight, but little excavated interambulacral walls, only the lanceolate plate at the anal side is toward the anus somewhat protruding.

Mr. Barris intends to describe this species through the Davenport Academy.—C. W."

The cheironym on the label over the note is "*Nucleocrinus bondi* Cal."

Position and localities.—The type specimen was found on the side of the wagon road, between the road and the left bank of Iowa river, a short distance south of the old Sanders quarry near the north limits of Iowa City. The rock here is the Cedar Valley limestone and is fifteen to twenty feet below the zone of *Strobilocystites calvini* found near the same place. The specimen was collected by Mr. Frank Bond, a student of Professor Calvin, about 1878, now at the General Land Office, Department of the Interior. Mr. Bond furnished the author with valuable information concerning the precise locality where this and other specimens were found. It is a pleasure to dedicate the species to him.

Another fine specimen was collected in 1864 by Mr. Anton Linder near the boathouse on his homestead in northeast quarter of the southeast quarter, section 33, township 80 north, range 6 west, about two miles north of Iowa City. This specimen is a part of the Fitzpatrick collection all of which has been most generously made available for this study. A third specimen also in the Fitzpatrick collection was found in the northeast quarter, section 30, township 80 north, range 6 west, along Rapid creek about four miles northeast of Iowa City. The right half of this specimen is imperfectly developed giving it a distorted appearance, and it is wider in proportion to its height than the others; in other respects it is typical. A young specimen, about 18 millimeters long, recently collected by the writer in the *Athyris* zone at Aicher's quarry, about three miles north of Iowa City, is tentatively referred to this species.

CRINOIDEA Miller
CAMERATA Wachsmuth and Springer
MELOCRINIDAE Zittel

A family of monocyclic crinoids which range from Ordovician to Devonian. Well defined interbrachials between the primibrachs and secundibrachs and forming a part of the dorsal cup. Radials in contact all around. Two genera are represented in the Iowa Devonian, stratigraphically they occur in probably the latest beds in which this family is found. The specialization attained by some of the species may be in keeping with their late appearance.

MELOCRINUS NODOSUS Hall

Plate XXXVII, fig. 1.

1861. *Melocrinites nodosus* Hall. Geol. Surv. Wisconsin, Rept. Prog., p. 19.

1881. *Melocrinus nodosus* Wachsmuth and Springer. Rev. Paleocr. II, p. 122.

1895. *Melocrinus nodosus* Whitfield. Mem. Am. Mus. Nat. Hist., vol. I, p. 48, Pl. V, fig. 14.

1898. *Melocrinus nodosus* Weller. Ann. New York Acad. Sci., vol. XI, No. 7, p. 118, Pl. XIV, fig. 6.

1911. *Melocrinus nodosus* Cleland. Wisconsin Geol. Surv., Bull. XXI, p. 38, Pl. 3, fig. 4.

"Calyx pyriform, truncate at the base, sides straight or slightly convex from the tops of the basals to the arm openings; cross-section, as seen from above, exclusive of the nodes, obscurely subpentagonal, greatest diameter at the arm bases. The plates of the dorsal cup ornamented with conspicuous nodes.

Basals four, projecting laterally into more or less prominent nodes, columnar facet large, often somewhat depressed between the nodes of the plates. Radials large, heptagonal and hexagonal, strongly nodose. First costals hexagonal, smaller than the radials, strongly nodose; second costals pentagonal or heptagonal, smaller than the first and less strongly nodose. Distichals smaller than the last costals, higher than wide, free beyond the first pair. First interdistichals hexagonal, as large as the first costals and

bearing similar nodes, followed by two smaller nodose plates in the second row, one of which often bears a larger node than the other; in the third row there are two or three smaller plates and above these numerous small plates which lead up to those of the vault. The posterior interradius is not differentiated from the other four.

Ventral disk depressed convex or nearly flat, composed of small polygonal nodose plates of nearly equal size; marked by more or less prominent rounded ambulacral ridges which extend from the arm bases towards the center; and surmounted by the base of a subcentral proboscis whose height cannot be determined."—After Weller, 1898.

Remarks:—Hall's type specimens were collected from limestone blocks in "the drift about Milwaukee" by I. A. Lapham, and at Iowa City by Barris, who presumably obtained the single specimen sent Hall, in the Cedar Valley limestone sometime during his pastorate at Iowa City in 1855-1859. It is a rather remarkable fact that no further specimens have been collected here so far as known although other examples have been obtained about Milwaukee. In Whitfield's republication of the species he has figured one of Hall's types. Doctor Chester A. Reeds of the American Museum of Natural History writes that "the type specimen of *Melocrinus nodosus* Hall is entered on our labels as having been found near Milwaukee, Wisconsin. A large and a small specimen without arms are represented. We have no reference that one or the other of these specimens was collected in Iowa."[31] Whitfield's figure is reproduced here. The Milwaukee specimens figured by Weller and by Cleland are considerably smaller than Whitfield's lectotype. This species is mentioned but not described by Wachsmuth and Springer in Crinoidea Camerata, volume I, page 294. Its nearest allies are *M. calvini* from the State Quarry beds of Iowa and *M. gregeri* from the Callaway limestone of Misouri. *M. nodosus* is much more nodose than either of these.

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31 Personal communication. February 27, 1922.

MELOCRINUS NODOSUS var. IRREGULARIS n. var.
Plate XXXVII, figs. 2-4.

This variety differs from typical *nodosus* in the arrangement of the plates of the posterior interradius which in the first row has a pentagonal plate, point downward, resting on the shoulders of two basals, followed by a single hexagonal plate in the second row and this by three plates in the next row while above these are a number of smaller plates grading into those of the tegmen. The other four iBr areas have a single large hexagonal plate followed by two plates in the next series, and so forth as in typical *Melocrinus*. In true *nodosus* the posterior interradius is not differentiated. Wachsmuth and Springer[32] say that in the genus *Melocrinus* the anterior radial is hexagonal since it "rests squarely on the anterior basal." The other radials are heptagonal. In the specimen at hand the hexagonal radial is at the base of the left anterior ray; all the other radials are heptagonal. These two irregularities may be abnormalities of an individual and further specimens must be sought before the points can be settled.

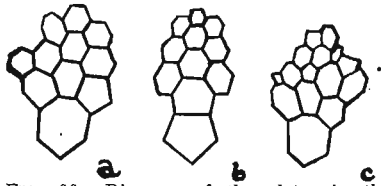

FIG. 66.—Diagram of the plates in the anal interray of three species of *Melocrinus*. Drawn to scale. a. *M. calvini*; b. *M. nodosus irregularis*; c. *M. tiffanyi*. The last is after Wachsmuth and Springer.

Height of specimen 26.3 millimeters, height of arm openings 19.0 millimeters, greatest width 19.5 millimeters, diameter of columnar facet 5 millimeters. Type specimen, number 3600, collected by Merrill A. Stainbrook in the Cedar Valley limestone along Lime creek one-half mile east of city limits of Brandon, Iowa, about ten feet above the *Acervularia davidsoni* reef.

MELOCRINUS TIFFANYI W. and Sp.
Plate XXXVII, fig. 5.

1897. *Melocrinus tiffanyi* W. and Sp. Crin. Cam. N. Amer., vol. I, p. 299, Pl. 22, figs. 7a, b.

"Calyx pyriform; the sides nearly straight from the

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32 W. and Sp., Crin. Cam. N. A., vol. I. p. 292; 1897.

top of the basals to near the bases of the arms; the tegmen depressed-hemispherical; cross-section, as seen from above, obtusely pentangular. Surface of plates ornamented by faint ridges, radiating from near the centre of the plates to the centre of adjoining ones.

Basals projecting laterally, forming four conspicuous, elongate nodes; the lower part somewhat excavated for the reception of the column. Radials and costals gradually decreasing in size upwards, about as long as wide; the second costals not more than half the size of the radials. Of the distichals two plates are preserved; the lower one fully one-half smaller than the preceding axillary; the second short, shaped like an arm joint and curving outwards. There are no interdistichals, all plates of the arm trunks being in contact laterally. Interradial areas on a plane with the radials and costals; the first interbrachial the same size as the radials, and followed in the type specimen by two plates at three of the sides, but in the posterior and right antero-lateral interradius by three, and these by numerous rows of from three to four plates, which connect with the disk pieces. Ventral disk depressed-hemispherical, the plates very uniform, rather large, having the size of the third row of interbrachials. They are ornamented like the plates of the dorsal cup, but are a little more convex. There are apparently no orals. Anus excentric, probably connected with a tube. Arms unknown; column round."—After Wachsmuth and Springer.

Remarks:—Type specimen which was in the Tiffany collection seems to be lost, at least "it could not be found at the time of Mr. Tiffany's final illness"[33].

Position and locality.—Cedar Valley limestone, Buffalo, Iowa.

MELOCRINUS CALVINI W. and Sp.

Plate XXXVII, figs. 6-8.

1883. *Melocrinus solonensis* Calvin. History of Johnson County, Iowa, Notes on the Fossils, p. 559 (no description).

1897. *Melocrinus calvini.* W. and Sp. Crin. Cam. No. Amer., vol. I, p. 300, Pl. 22, fig. 6.

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33 Frank Springer, personal communication, Feb. 12, 1920.

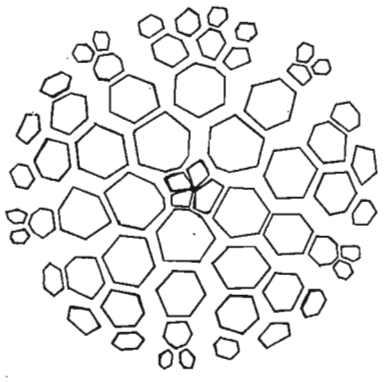

FIG. 67.—Analysis of calyx of *Melocrinus calvini* W. and Sp. Note that the first plate in the anal interray is heptagonal and that it is followed by three plates in the next range.

"Similar to the preceding species, but the sides of the dorsal cup convex, and the general form of the calyx subovoid; the basals less projecting; the radials, fixed brachial and interbrachials—the latter to the third row—crowned by a large, rather conspicuous rounded node without other ornamentation; the upper interbrachial and interambulacral plates a little convex. Basals projecting laterally, and forming four rather conspicuous nodes around the columnar attachment which is a little projecting. Radials and costals longer than wide. The distichals of the same rays in contact laterally. Regular interbrachial spaces large, but slightly depressed between the arm trunks; the plates arranged: 1, 2, 3, 3, the upper ones insensibly connecting with the plates of the ventral disk. Anal interradius widest, having three plates in the second row. Ventral disk short; the plates rather small and of uniform size; orals apparently unrepresented. Anus excentric, probably at the end of a narrow tube."—After Wachsmuth and Springer.

Position and locality.—Type specimen from the State Quarry limestone at Solon, Iowa[34]. It is number 3601 University collection. No further specimens have been collected at any of the State Quarry outcrops; crinoid stems, however, are not rare.

MELOCRINUS (?) LINDERI n. s.
Plate XXXVII, figs. 9, 10.

Calyx conical, width and height about equal; cup expanding gradually from the base, widest just before reaching the arm bases. Dome low, each of its numerous plates bearing a delicate central spinule. The preserved plates of the cup are marked by sharp spinose central nodes but are otherwise smooth.

[34] Geol. Surv. Iowa, vol. VII, p. 78.

Species is nearest to *M. calvini* of the State Quarry beds but is more spiny. In *M. linderi* the iBr and upper plates of the brachial series are sharply nodose while in *calvini* only the radial series bear spiny nodes above iBr_2. Moreover, the type of *calvini* is suboval in cross section near the arm bases, in *linderi* the same section is nearly circular. It resembles also *M. gregeri* but is smaller and narrower than Rowley's type. Better material may prove them identical.

The only specimen at hand is incomplete. It was preserved in a cherty nodule and on its removal the basals and a part of one side were broken off. An area between iBr_1 and the arm bases extending about one-third the circumference of the calyx preserves the surface and shows the spiniferous plates. The remainder of the surface is exfoliated but over this part the outlines of the plates can be distinctly traced. The plan is quite clearly that of *Melocrinus* but the absence of basals makes generic reference a little doubtful.

Position and locality.—In the Cedar Valley limestone at Indian Hollow on right bank of Iowa river opposite the mouth of Turkey creek, section 21, Penn township, Johnson county, Iowa. Collected by Mary Frances Linder for whom the species is named. Type specimen in the Fitzpatrick collection.

MELOCRINUS BELANSKII n. s.
Plate XXXVII, figs. 11-16.

Calyx bowlshaped, abruptly spreading, apparently much wider than high, sides convex. Plates smooth, slightly raised, edges depressed making broad grooves along the suture lines; inner surface of plates bearing centrally a cluster of irregular nodes and ridges which are more or less radially arranged. The edges of the larger plates are in some cases delicately milled.

Basals four; they project downward and form a shallow inverted cup with a sharp rim which is deeply notched at the interbasal suture. The plates are subequal, the two on the right being quadrangular, the other two, pentangular. The latter are larger and their outer surfaces slope less abruptly than the

former thus deforming in a slight degree the basal cycle and giving the stem a subcentral position.

Radials five, hexagonal, length and width about equal; posteriorly they are separated by a five-sided plate—presumably the anal, thus making six plates in the second cycle. Four of the five radials are much alike in size and general proportions but the base of the fifth (the left posterior) is only about half as wide as the base of the others; morover, the surface of the calyx between this plate and the left anterior radial is considerably depressed. IBr_1 hexagonal, wider than high, each followed by a somewhat smaller pentangular axillary or IBr_2 which is followed by two IIBr of decreasing size. Plates beyond this unknown.

Column round, five millimeters in diameter inside the basal ring; axial canal small, about 0.8 millimeter in diameter, obscurely pentalobate. Associated with the type specimen were several loose plates and numerous fragments and columnals of a large round stem whose side-faces are in some cases ornamented with tubercles. The segments are assumed to belong to this species and a few of them are illustrated.

The presence of six plates in the second cycle is not characteristic of *Melocrinus* but the irregularity in the type specimen here described is regarded as an abnormality. Unfortunately the plates following the anal are lost; it would be interesting to know whether or not the anal was followed by three plates in the range next above as is usual in this genus, or by less than three due to its unusual position.

Troost's genus *Turbinocrinus* (*Turbinocrinites*), proposed in manuscript, has four basals and "the first plate of one of the interradial spaces truncating one of the basal plates"[35], that is, the extra plate is on a level with the radials as in *M. belanskii*. There is some question, however, about the proper interpretation of Troost's specimen[36].

Type specimen collected in southeast quarter section 13, township 95 north, range 19 west, by C. H. Belanski, also the separate fragments mentioned above and referred to this

35 Twenty-eighth Ann. Rept. New York St. Mus. Nat. Hist. (Museum Edition), p. 139; 1879.
36 Wachsmuth and Springer, Crin. Cam. North America, vol. I, p. 294; 1897.

species. Isolated pieces of the stem and plates occur at several stations in the Lime Creek fossiliferous beds near the top of the Iowa Devonian.

Stereocrinus Barris.

Barris, Davenport Acad. Sci. vol. II, p. 282, 1878; vol. IV, pp. 102-104, 1886; and Wachsmuth and Springer, No. Amer. Crin. Cam., vol. I. pp. 324, 325, 1897.

Calyx depressed, wider than high, flattened below; basals three, forming a pentagon; RR, hexagonal; IBr, one, pentagonal, axillary; IIBr, two or three; iBr, two, one above the other, the first heptagonal, the second hexagonal, and followed by a range of three. Arms biserial, ten in number, that is, two for each ray; spaces between arm bases depressed. Dome low, pentalobate; anal opening apparently at end of a subcentral tube. Slitlike apertures near bases of arms. Column round.

This genus is found in lower part of Cedar Valley and Upper Wapsipinicon beds of Iowa and in equivalent or somewhat older strata in northern part of southern peninsula of Michigan. Springer has recently described an interesting species of the genus from the Helderbergian of Benton county, Tennessee[37].

Stereocrinus triangulatus Barris.

Plate XXXVIII, figs. 1-3.

1878. *Stereocrinus triangulatus* Barris. Proc. Davenport Acad. Sci., vol. II, p. 283, Pl. 11, figs. 1, 2; also note on page 288.

1881. *Stereocrinus triangulatus* W. and Sp. Rev. Paleocrin., II, p. 127.

1897. *Stereocrinus triangulatus* W. and Sp. No. Amer. Crin. Cam. I, p. 325, Pl. 25, figs. 8a, b.

"Body large; breadth to height as two to one. Basal pieces solidly anchylosed, and either as a narrow rim clings closely to the column or widens into a pentagon, on each side of which rests the first radial. First radials large, hexagonal, the centers of which are con-

37 Springer, F., Bull. 115, U. S. Nat. Mus., p. 15, Pl. V, figs. 3, 4; 1921.

nected together by ridges, forming a pentagon, the angles of which are equi-distant from the angles of the inscribed pentagon forming the base. Second radials pentagonal, nearly the size of the first radial. First supraradials about half the size of the second radial, pentagonal or hexagonal, resting mainly on the sloping upper side of the second radial, and partly on the interradial, broader than high. The second supraradial, or rather brachial, is of irregular triangular shape, broader than high, whose base is nearly the breadth of the supraradial. First interradial large as first radial, heptagonal, higher than broad. This sustains a second interradial hexagonal, not more than half the size of the first. This is crowned by three small irregular plates, arching from arm to arm, surmounted by another series of three, somewhat smaller. The summit is elevated in the centre. From each series of arms, extending towards the center, is a ridge of larger plates, giving a five rayed aspect to the summit. Plates roughened and tuberculiform.

Proboscis sub-central.

The ornamentation consists of a series of triangles enclosed one within the other, the outer of which—the enclosing triangle—heads in the center of the larger plates. meeting there the apices of as many series of triangles as there are sides of the plates.''—After Barris, 1878.

The type specimen was collected in the upper Davenport beds, in bed number four of Barris. It is now in the Museum of the Davenport Academy of Science. Two specimens, numbers 3628 and 3629, in the University collection, are from the Wapsipinicon beds at Solon. They are smaller than the type and are partly exfoliated but enough of the original surface is left to show the characteristic markings. Barris' variety *liratus* has not been seen. Wachsmuth and Springer regard it as not sufficiently distinct for separation. It is apparently a young individual. In the Fitzpatrick collection is a specimen preserving the base of the cup. It shows the smooth pentagon of anchylosed basals, the radials, a few brachials and interbrachials. The characteristic ornamentation is unusually well preserved. (See figure 3, plate XXXVIII.)

STEREOCRINUS LITTLETONENSIS n. s.
Plate XXXVIII, figs. 4, 5.

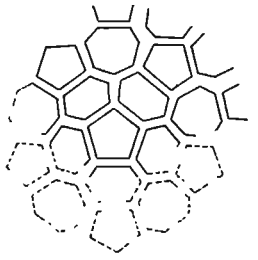

FIG. 68.—Analysis of the plates of *Stereocrinus littletonensis* in so far as they can be made out with certainty. Note the perfect symmetry.

Calyx of about the same width as the type of *S. triangulatus* but shallower. The markings, too, are of the same triangular pattern but are not so prominent. The plates of the cup are further adorned by stout, blunt, central spinelike nodes. Those on the RR are broken off; those on the IBr, IIBr, and iBr plates are directed outward and downward; they are from three to six millimeters in length, and from three to six millimeters in diameter at the base. The raised lines which mark the plates ascend part way up the shafts of some of the "spines." Dome lacking. Stem, large, round.

Type specimen collected among the corals of the *Acervularia profunda* reef in the valley of Dry Run near Littleton, Iowa, by Samuel Calvin[38]. Its horizon is near the base of the Cedar Valley. Wachsmuth and Springer, Crinoidea Camerata, I, page 325, mention having an imperfect specimen of an undescribed species from Waterloo, Iowa. This may well belong to this species since the rocks at the two localities are approximately at the same horizon.

BATOCRINIDAE Wachsmuth and Springer

A family of monocyclic crinoids with three (rarely four) basals followed by five RR and a seven-sided anal plate in the next cycle. Anal plate followed by three plates in the next range. In the subfamily Batocrininae the first IBr is quadrangular, in the subfamily Periechocrininae this plate in most cases is hexagonal. *Megistocrinus* belongs to the latter.

MEGISTOCRINUS FARNSWORTHI White
Plate XXXVIII, figs. 6-12.

1876. *Megistocrinus farnsworthi* White. Proc. Acad. Nat. Sci. Philadelphia, vol. 28, p. 29.

38 Bull. Lab. Nat. Hist., Univ. Iowa, vol. 2, p. 181, 1891-1893.

1881. *Megistocrinus farnsworthi* W. and Sp. Rev. Paleocr., pt. II, p. 138.

Not *Megistocrinus farnsworthi* W. and Sp., Crin. Cam. No. Amer., vol. II, p. 539, Pl. XLVIII, figs. 4a, b.

1904. *Megistocrinus farnsworthi* Wood. Smith. Misc. Coll., vol. 47, p. 64.

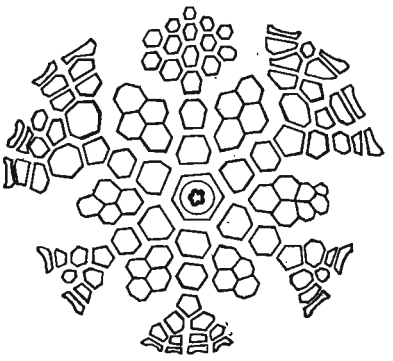

FIG. 69.—Analysis of the calyx of the more perfect of the type specimens of *Megistocrinus farnsworthi* White.

Calyx small for this genus; cup truncate below, the basals depressed, RR in horizontal position; sides of cup gradually spreading to the arm bases. Dome broadly convex and composed of many small tumid plates; anus subcentral and apparently at the upper end of a small tube.

BB three, forming a closely anchylosed hexagonal piece, partly covered by the stem which has a pentalobate lumen. RR five, wider than long, separated by an anal plate which is slightly narrower than the radials and is more nearly hexagonal than heptagonal in shape—the latter being the common shape in this family; upper lateral edge longer than the lower. IBr_1 hexagonal, equal to or larger than the BB, curved, and followed by a pentagonal axillary; IIBr three in the antero-lateral rays and but one, a large axillary, in each of the other three; IIIBr form a series of three or four below each of the four arms in the anterior and in the two posterior rays; iBr plates fairly large, the first resting point downward on the shoulders of the RR and followed by a series of two plates and these by a number of smaller pieces. Anal plate followed by three plates in the next rank likewise the suranal is followed by three in the next range, above this there are a number of small pieces to the arm bases. Arms sixteen, four in the anterior ray and in each of the postero-lateral rays, and two in each of the other rays. Arm openings directed upwards.

Plates smooth, margins depressed so as to form wide sutures

which are characteristic of this species, except immediately below the arm bases where the depressed marginal areas are still wider and the plates are tumid centrally. Stem round, its proximal columnal but partly covering the basal hexagon. Lumen pentalobate.

The better of the two cotypes is 22 millimeters high and 28 millimeters across the base of the arms, height of dorsal cup 14 millimeters.

Remarks.—White's types, which have not been figured heretofore, are quite distinct from the large thick-plated, high-domed *M. robustus* from Solon, next to be described, which has long been identified under the same name. Calvin extended White's name to include the Solon species, and specimens from Solon were distributed under the name, *M. farnsworthi* White. Wachsmuth and Springer illustrate specimens from Solon and their description of *M. farnsworthi* seems to have been based on specimens from that locality.

Position and localities.—The types of this species were collected in the Cedar Valley limestone near Iowa City by Dr. P. J. Farnsworth. There is one fine specimen in the Calvin Collection from the Cedar Valley beds at Littleton[39]. In the Fitzpatrick collection is a fragment of a calyx slightly larger than the others at hand and in which the basal cycle projects a little beyond the radials—otherwise it is quite typical. It was collected at one of the numerous exposures in the vicinity of Linder's boathouse. Recently, Mr. Walter V. Searight, a student at the University, found a specimen which is almost a duplicate of one of White's types. The specimen was collected along the right bank of Iowa river north of Iowa City in the east half of section 28, township 80 north. Since the precise locality where Farnsworth obtained the types is unknown, Mr. Searight's find is of special interest. Apparently, recognizable calyces are not common.

Megistocrinus robustus n. s.

Plate XXXIX, figs. 1-5.

1897. *Megistocrinus farnsworthi* W. and Sp. Crin. Cam. No. Amer., vol. II, p. 539, Pl. XLVIII, figs. 4a, b.

39 Bull. Lab. Nat. Hist., Univ. Iowa, vol. 2, p. 183, 1891-1893.

Calyx large, robust, mature specimens coarse and thick-plated. Base truncated, hollowed out centrally. Dome strongly convex to conical and quite as high above the arms as the arms are above the base; dome plates tumid, smooth, fairly large and separated by distinct sutures; above the arm bases are strong ridges which extend well up on the dome of most specimens giving the vault a radially fluted appearance. Anus subcentral and apparently at the end of a strong tube.

Arrangement of plates much as in *M. farnsworthi* but with a larger number of pieces in the anal interray. Basal hexagon almost wholly obscured by the stem. RR horizontal in position, anal smaller and narrower than the other plates of the radial cycle. The IBr and iBr_1 plates larger than the radials, the first IBr bent upward at the angle of cup's base.

Arms sixteen (a few with but fifteen), bases protruding strongly and on most specimens the protrusion is greater on one side giving the calyx a lopsided aspect. Arm openings directed outward and slightly upward.

Plates of cup thick and swollen except those of the radial cycle which are flat and smooth and with flush edges; the broad depressed margins of the plates above the radials result in wide sutural grooves.

The type, number 3604, is 43 millimeters in height and 51 millimeters in greatest breadth at base of arms.

Remarks.—An occasional specimen in the lot referred to this species has a rim at the arm bases which is the result of the extension of the iBr and domeplates into the areas between the arms. Other specimens have rather low nodes on plates of the cup and the plates up near the arm bases are faintly nodose, in this respect approaching *M. fitzpatricki.*

Position and localities.—The type locality is near Solon where the abundance of crinoidal remains in the lower strata of the Cedar Valley led Calvin to call them the "Megistocrinus beds." Occasional specimens have been collected at Aicher's quarry and a few at Linder's boathouse, both places along the river north of Iowa City. Several specimens have been found along Rapid creek in sections 20 and 21, township 80 north, range 5 west, and on down the creek through range 6 west. In

the Calvin collection is a worn specimen from Dry Run near Littleton; it is tentatively referred to this species. There is a small but quite perfect specimen from Linder's boathouse in the Fitzpatrick collection.

MEGISTOCRINUS FITZPATRICKI n. s.

Plate XXXIX, figs. 6, 7; plate XLVI, figs. 10, 11.

Species based on eight or ten specimens of more or less perfect calyces the largest of which has no tegmen but a well preserved dorsal cup. This is made the type. The general plan of the plates, so far as they can be determined, is close to that of *M. farnsworthi*. The calyx is of moderate size, the cup is broadly bowl-shaped, the tegmen is low and gently convex. Lower part of cup flattened as far as the first primibrachs above which the sides are inflated as far up as IBr_2 or $IIBr_1$. From here the cup contracts slightly to the arm bases, where it is again a little expanded. Height of arm bases a little less than one-half the width of the cup. The greatest width of the type specimen is five centimeters and is taken at the level of the lower edge of $IIBr_1$.

Base hexagonal, hidden by the proximal stem segment. Six plates in second cycle all hexagonal, wider than long—in the type the anal and the two contiguous radials are smaller than the other three. IBr_1 hexagonal, IBr_2 pentagonal and axillary, the area of each nearly the same as that of the radial below; the last IBr is followed by two plates in the next series, those whose sutures can be traced being five-, six-, or seven-sided. Above these secundibrachs the succession is obscure.

Interradial areas characterized by a large hexagonal IBr_1 longer than wide. This is followed by two plates in the next series, the most of which are six-sided, though five- or seven-sided ones occur. Beyond these the succession is obscure.

The stem is strong, round, and has a large lumen. In the type it is subcentral in position and as a result of this asymmetry the anterior part of the cup bears larger plates than the posterior part as indicated above.

Arms sixteen, tending to be paired, bases protruding slightly.

Tegmen low, made up of small, smooth plates; anus subcentral and evidently at upper end of a short tube.

The surface of the calyx is finely granulose; toward the edges of the plates the granules grade into fine elevated ridgelets which meet the sutures at right angles; each plate is marked centrally by a low but distinct node; the margins of each plate are abruptly elevated in such a way that the common contact of two plates forms a definite ridge along the suture line. The granules, central nodes, and sutural ridges become weaker distally and practically disappear before reaching the arm bases.

The species differs from *M. robustus* in the more evenly rounded bowl-shaped cup, in the markings of the plates, and in the elevated rather than depressed sutures.

Position and localities.—The specimens studied were collected near Linder's boathouse about two miles north of Iowa City by Professor T. J. Fitzpatrick to whom the species is dedicated. A band of dark limestone three to six inches thick, a few feet above where *M. fitzpatricki* is said to have been collected, is filled with segments of a very large crinoid stem, some of which reach a diameter of sixteen millimeters. No other recognizable parts of a crinoid have been found in this layer. (See figure 7, plate XLVI.)

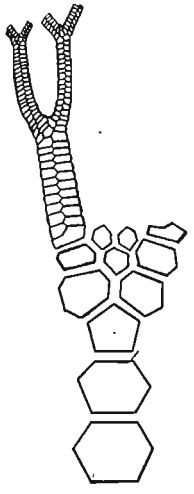

FIG. 70.—Plan of left anterior radial series and of part of the arm of the type specimen of *Megistocrinus clarkei*.

MEGISTOCRINUS CLARKEI n. s.

Plate XL, figs. 1-8; plate XLVI, fig. 9.

A large subglobose calyx with truncate base, somewhat depressed centrally. Sides of cup broadly rounded, widest at arm bases in all specimens observed but one—this reaches its greatest width three or four millimeters below the arms. Dome strongly convex and fully as high as the dorsal cup. Specimens silicified and as a result some of the sutures are entirely obliterated, others are quite distinct, while on parts of nearly every calyx are irregular areas on which the plates are smooth as if polished and where the sutures are readily traceable.

Arrangement of plates as in typical species of this genus; the primibrachs and first interradials are fully as large as the radials. The anal plate is a little smaller than the radials and is followed by a six-sided suranal which is flanked on either side by a large iBr; above the suranal is a vertical series of three or more plates in continuous succession—the whole anal interray, up to the level of the arms, containing twenty to twenty-five plates.

Dome composed of a large number of small polygonal plates and of even contour except for low ambulacral ridges just above the arm-bases; anus subcentral, consisting of an oblique opening through the tegmen and directed toward the center of the dome, its rim smooth, slightly thickened, and raised except on the proximal edge.

Plates of cup smooth, dome plates slightly granular on a few specimens; between the radials and adjoining plates the sutures are a little elevated, as in *M. fitzpatricki;* above these the edges of the plates are flush except on parts of the dome where the sutures are a little grooved. A faint central node marks the IIBr, and IIIBr, and also the iBr plates of the upper part of the cup.

Arms sixteen, rather weak, directed outward and upward in a sharp curve; biserial throughout, branching dichotomous and frequent; eleven to thirteen pieces on each side between base of arm and the first bifurcation, sixteen to eighteen between the first and second bifurcation, above this unknown. Pinnules small and slender, and conspicuously jointed about one millimeter above the base of each.

Stem round, fairly stout; lumen large, pentalobate.

This species has been repeatedly identified as *M. farnsworthi;* it differs from it, however, in its larger size and more globose calyx, in having smooth plates without grooved sutures, especially in the lower cup, and in the absence of an anal tube —in the last respect it differs from all the members of the genus in our area.

This crinoid is already well known[40] to paleontologists from

40 Clarke, J. M., "Beginnings of Dependent Life": Adv. sheets Fourth Ann. Rept. Director Sci. Div., p. 23, text figs., Albany, New York, 1908.

the fact that it habitually harbored a large parasitic limpet; their consociation was discussed by Clarke many years ago and again more fully in a recent publication[41]. This gastropod attached itself to the tegmen of the crinoid in such a way as to keep the anterior part of its round-mouthed shell over the anal aperture of its host. Its purpose obviously was to feed upon such refuse matter as the crinoid eliminated from its alimentary canal. That its attachment was a permanent one and not casual is proved by the perfect adaptation of the margin of the snail's shell to the irregularities of the crinoid's vault as shown in the illustrations. The smooth round dome and the absence of an anal tube as found in other species favored the establishment of the parasite while the weak, slender, and well separated arms of the crinoid made approach the easier. Of the calyces at hand, fourteen of them preserve the tegmen sufficiently well to be examined for traces of the snail's occupancy; of these eight, or over fifty-seven per cent, show that they were unquestionably the unhappy hosts of a weighty and persistent parasite. These figures illustrate most convincingly how completely fixed had become the association of this crinoid and its dependent snail, *Platyceras*. This genus of snails is not common in the Iowa Devonian; a few specimens have been found in the Cedar Valley mainly near Solon and also at Linder's boathouse north of Iowa City, but not one of them has ever been reported attached to a crinoid and no free specimens have been collected which are similar to the parasite[42] under discussion.

The preservation of this species is worthy of brief comment since it is our only silicified crinoid, except the holotype of *Melocrinus linderi;* in the horizon where it occurs, however, nearly all the associated fossils are thus altered and there is considerable chert with the limestone. The rough, silicified plates of the crinoid show pitted centers about which are ar-

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14 Clarke, J. M., "Organic Dependent and Disease," p. 71, fig. 58, New Haven, 1921.

42 *Platyceras inoptatum* n. s. A robust, capacious, holostomatous shell, abruptly expanding from a small dextrally coiled apex. Aperture broadly oval to nearly circular, its margin conforming to the irregularities of the test of the host. Shell marked by numerous crowded lines of growth. Length of shell along curvature from front margin to apex, six centimeters; from posterior margin to apex, one centimeter; antero-posterior diameter of aperture, 31.5 millimeters, transverse diameter of aperture, 28 millimeters. Type attached to specimen number 3623.

ranged rudely concentric rings of siliceous matter. The outer surfaces of the smooth plates are but thin, siliceous shells supported by vertical partitions along the suture lines; when the surfaces of the smooth plates break away the appearance is similar to that of the prismatic ends of favositoid corallites. Among the specimens at hand are four or five large globose balls of cherty matter about twice the size of the average calyx. On the surfaces of these are the plates of the cup and dome, their relative positions and orientations still rudely preserved but all separated and held fast in their places in the cherty chalcedonic mass which apparently originated in the interior of the calyces.

It is a pleasure to dedicate this species to Dr. John M. Clarke, state paleontologist of New York, whose masterly studies of the forms of life in the Paleozoic have a wide bearing which extends far beyond the field of academic speculation.

Position and locality.—About the level of the *Acervularia profunda* zone near the base of the Cedar Valley limestone at Waterloo, Iowa. The specimens were found in some small abandoned quarries on the west side of Cedar river near the south line of the city limits and but a few blocks from the stream. They were obtained many years ago by Mr. and Mrs. David Brant, enthusiastic collectors of natural history specimens. Four specimens, including the one illustrated by Clarke, were given by them to Professor Calvin. Recently Mrs. Brant generously turned over the remaining specimens to the writer for study. Unfortunately that part of the city where the specimens were found has now been largely built over and the original location is covered up.

MEGISTOCRINUS LATUS Hall.

Plate XLI, fig. 1; plate XLV, fig. 3.

1858. *Actinocrinus* (*Megistocrinus*) *latus* Hall. Geol. Surv. Iowa, vol. I, pt. II, p. 480, Pl. I, figs. 1 a, b.

1881. *Megistocrinus latus* Wachsmuth and Springer. Rev. Paleocr., Pt. II, p. 138 (in a list).

1897. *Megistocrinus latus* Wachsmuth and Springer. Crin. Cam. N. A., vol. II, p. 538, Pl. 48, figs. 3 a, b.

1904. *Megistocrinus latus* Wood. Smith. Misc. Coll., vol. 47, Pt. II, p. 66 (in a list).

> "A large species. Dorsal cup short, about twice as wide as high, abruptly depressed at the bottom; the sides expanding upwards; arm bases slightly projecting; plates flat and without ornamentation; suture lines grooved.
>
> Basals closely anchylosed, rather large, located at the bottom of an inverted cup, which is a little wider than the column. Radials about as wide as long; their lower ends abruptly curved to form the sides of the basal concavity, the other portions spreading horizontally and constituting the bottom of the calyx. First costals generally longer than the second. Distichals in the antero-lateral rays three, supporting two arms; the other rays have a single axillary, followed by several palmars with four arms to the ray. Interbrachials: 1, 2, 3, 3, and some small pieces between the arm-bases. The first anal plate, which is a little narrower than the radials, is succeeded by three plates, and these, by numerous irregularly arranged pieces, which decrease in size upwards. Interdistichals one or two, placed longitudinally. Ventral disk hemispherical; the plates nearly flat and of irregular arrangement; orals and radial dome plates a little larger and convex. Anus subcentral. Column strong, the axial canal large and obtusely pentangular."—After Wachsmuth and Springer, 1897.

Horizon and locality.—A single specimen of this large crinoid, lacking the dome, was collected near Iowa City by Mr. L. P. Elliott. It was found in the Cedar Valley limestone and its horizon may be a little higher than that of Hall's type from Buffalo or that of Wachsmuth and Springer's specimen from the Tiffany collection. Udden reports this species from the *Spirifer parryanus* zone of Muscatine county[43].

Two imperfect calyces from the type locality were recently collected by the Reverend Mr. Hauber of St. Ambrose college.

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43 Iowa Geol. Surv., vol. IX, p. 282; 1899.

They show well the large smooth radials and other plates characteristic of the species. A calyx collected by the writer near North Liberty, mentioned above under localities of *Strobilocystites calvini,* further extends the distribution of the species.

Remarks.—The Iowa City specimen when found was covered with a coating of hard foreign material, the removing of which obliterated the surface characters of the plates. Posteriorly the cup turns abruptly upward resulting in a reduction of the number of plates and other abnormalities. Four of the radials are normal hexagonal plates, the other two, posteriorly situated, are one smaller and one larger than the others and are five- and seven-sided respectively. Neither is followed by the proper succession of plates but a study of the three anterior radial series brings out the proper orientation and it is found that the small pentagonal plate followed by two hexagonal pieces in the next range and these by a number of smaller pieces is the anal. The heptagonal radial is right posterior in position and is followed by a pentagonal plate and this by two fairly large plates in the same range.

Megistocrinus nodosus Barris.
Plate XLI, figs. 2-4.

1878. *Megistocrinus nodosus* Barris. Proc. Davenport Acad. Sci., vol. II, p. 285, Pl. 11, fig. 4.
1881. *Megistocrinus nodosus* Wachsmuth and Springer. Rev. Paleocr., Pt. II, p. 138 (in a list).
1885. *Megistocrinus nodosus* Barris. Proc. Davenport Acad. Sci. vol. IV, p. 98, Pl. 1, fig. 8; Pl. 2, fig. 2.
1897. *Megistocrinus nodosus* Wachsmuth and Springer. Crin. Cam. N. A., vol II, p. 541, Pl. 49, figs. 5 a, b.
1904. *Megistocrinus nodosus* Wood. Smith. Misc. Coll., vol. 47, II, p. 65.

> "A large species. Dorsal cup broadly urn-shaped, the truncated part embracing basals, radials, and first anal plate, which are in about the same plane; the sides of the cup which rise from the lower end of the first costals, slightly convex, expanding near the arm

bases. Plates without ornamentation; but the costals and interbrachials of the two proximal rows are somewhat nodose, while the radials are slightly convex, and the distichals and upper interbrachials almost flat.

Basal disk but very little projecting beyond the column, the columnar facet excavated and surrounded by a well defined circular rim. Radials and costals increasing in width upwards; the radials longer than wide; the costals wider than long. The highest orders of brachials arranged as in preceding species (*M. depressus*). Arms sixteen from the calyx; long, slender, bifurcating, and composed of a double series of interlocking pieces. First interbrachial as large as the first costals; followed by three or four rows of two plates each. First anal plate succeeded by 3, 4, 4, and 3 plates. Interdistichals two to three. Tegmen highly convex, somewhat inflated posteriorly, the interradial and interaxillary spaces deeply grooved from half way down to the arm regions; the posterior groove broadest and deepest; the surface paved by numerous irregular pieces, among which the orals are larger, subspinous, and not in contact; the radial dome plates strongly nodose. Anus subcentral. Column large."—After Wachsmuth and Springer, 1897.

Position and localities.—Barris' specimens were collected both at Alpena, Michigan, and near Davenport, Iowa. A very large example, partly embedded in a tough matrix, was collected at Cook's quarry in Davenport, in the Cedar Valley limestone. On this specimen the nodes are considerably larger and extend farther up on the calyx than they do on most of those from Alpena. The Cook quarry specimen is in the collection of the Davenport Academy of Science. Barris' type specimen, also collected at Cook's quarry and described in the Davenport Academy Proceedings, volume II, has not been studied by the writer. It is not with the other specimens at the museum.

MEGISTOCRINUS MERRILLI n. s.

Plate XLV, fig. 7.

Species based on the basal parts of a calyx preserving three cycles of plates. BB three, united, forming a hexagon, and not

projecting as a rim around the stem facet. RR five, hexagonal, wider than long, except the plate assumed to be the right posterior radial and the anal whose widths and lengths are nearly equal. This cycle of plates is horizontal in position. IBr averaging a little wider than long and increasing in width distally; the suranal and iBr plates longer than wide, the latter resting point downward on the shoulders of two radials. All plates in the second and third cycles are hexagonal. The third cycle plates are bent gently outward and upward about their midlength thus giving the calyx a broad flat base. Plates smooth, sutures flush; a low round central node is present on each of the plates of the third cycle. In diameter the node is from one-fourth to one-third the width of the plate. Each plate of the second cycle bears a shallow median depression. In the same zone and near the same place was found a large calyx whose cup is broken and considerably exfoliated. Its arm bases are strong and well separated; the plates near the base of one arm and a part of the dome are preserved well enough to show that they are not nodose. This specimen (No. 3766) may belong to the same species but the evidence is only circumstantial.

This species approaches *M. nodosus* but the latter has convex rather than depressed RR, its third cycle of plates is nearly vertical in position, and its RR are longer than wide. Some of the free plates assigned to *Megistocrinus pernodosus* from east of Brandon are somewhat similar to the nodose plates of the third cycle of this species but in *pernodosus* they are stouter and in nearly all cases they cover more of the plate.

Position and locality.—Cedar Valley limestone, *Acervularia profunda* zone, 1¼ miles southwest of Brandon, Iowa. Collected by and named for Mr. Merrill A. Stainbrook.

MEGISTOCRINUS PERNODOSUS n. s.

Plate XLI, figs. 5-23.

Species known from disconnected plates and pieces of stems all closely associated in a narrow shaly zone. Fortunately several sets of anchylosed basals are in the lot—to one of these basals is attached a single radial.

BB three, of equal size, forming a hexagon with sides alter-

nately long and short; plates closely anchylosed but the interbasal sutures are distinct; axial canal large, pentalobate.

RR hexagonal, extending horizontally and slightly downward suggesting a moderately broad and excavate base; the attached radial bears a strong transverse node which lies across the plate and is crescentic-oval or reniform in cross section, the distal side being convex and the proximal gently concave; several loose plates in the collection are identical with this one and are assigned to the same position in the calyx. A few of the plates are bent similar to IBr_2 in the cup of *M. robustus* suggesting a sharp upturning of the sides of the calyx.

The loose plates occur abundantly; they are thick, heavy, and polygonal—mainly hexagonal or pentagonal—and each bears a large prominent node which is smooth and of varying contour. In some cases the nodes are quite round, high, and centrally placed, in others they appear as thick swellings that cover the

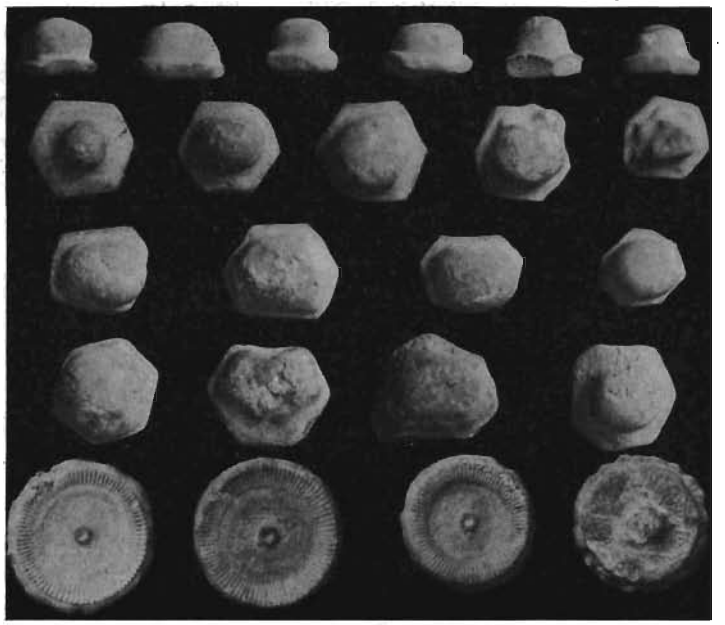

FIG. 71.—Nodose plates and stem segments of the crinoid *Megistocrinus pernodosus*. The left figures in the second and fourth rows illustrate by comparison the minimum and the maximum amount of surface covered by the nodes. Stem segments show the usual features of the joint face as well as the peripheral nodes. Enlarged.

whole plate and conform to its general outline; on several plates the nodes are noticeably constricted at their bases and in a few cases a low platform surrounds the node base. The height of a node is variable but in most cases it is fully one-half the diameter of the plate which bears it; on some of the smaller plates, possibly iBr or dome plates, their height is fully equal to or greater than the plate diameter. The edges of all plates are marked by an intricate pattern of low labyrinthine ridges which are conspicuous under a lens, especially on somewhat weathered specimens.

Accompanying the plates are abundant columnals and pieces of a large, round—rarely subpentagonal—stem presumably belonging to this species. In these the lumen is small and pentalobate and surrounded by a sharply elevated rim rising from the central area on both joint-faces of the columnal. The floor of the central area immediately surrounding the rim of the lumen is so thin as to be translucent. Some of the columnals bear a circlet of low peripheral nodes on their side faces. Short pieces of the stem are characterized as a rule by having alternate columnals wider and thicker; the side faces of the thicker columnals are not parallel to the axis of the stem but are bevelled in such a way that they have a large and a small circumference; the row of encircling tubercles follows the major circumference.

Remarks.—Judging from the abundance of detached plates and stems this species was very common at the horizon throughout which it is found. The calyx evidently is large and has a broad truncate base attached to a strong stem. The highly nodose character of the plates is more marked than in any other species of the genus and reminds us of those of *Melocrinus nodosus irregularis* of the same locality and at nearly the same horizon. The six-sided base, the horizontally placed radials, and the large size of the plates and stem columnals make reference to *Megistocrinus,* however, reasonably safe. *M. concavus* Wachsmuth is another Devonian crinoid with knobby plates. It has not been reported from Iowa but does occur with *M. nodosus* and others at Alpena, Michigan. The radials, however, of *M. concavus* are not nodose and none

of the specimens at hand or of the published illustrations shows transverse nodes such as are present on the radials of *M. pernodosus.*

Position and localities.—Limestone beds of the Cedar Valley above the coral reef along Lime creek, Buchanan county, and at the same horizon in the interurban railway cutting east and south of Brandon, Iowa. About forty rods north of the Brandon cemetery and west of the diagonal road in southwest quarter, section 23, township 87 north, range 10 west, is a small gully which leads down to Lime creek. The floor of the gully for some distance is in limestone rock the upper stratum of which is a crinoidal layer six to ten inches in thickness crowded with stem segments and the nodose plates of this or of a similar species. A long search yielded no calyces.

HEXACRINIDAE Wachsmuth and Springer

A family of monocyclic crinoids which is very common in the Devonian of Europe but is rather sparse in the American Devonian. BB three or two, forming a hexagon; RR five, separated posteriorly by an anal plate. Represented in the Iowa Devonian by three species of *Hexacrinus* and by one of *Arthracantha.*

HEXACRINUS OCCIDENTALIS W. and Sp.
Plate XLII, fig. 1.

1897. *Hexacrinus occidentalis* W. and Sp. Crin. Cam. No. Amer., vol. II, p. 745, Pl. 78, fig. 10.

> "A small species. Dorsal cup higher than wide, broadly truncate at the base, very gradually spreading to the arm bases; the sides a little convex; the plates moderately thick and without ornamentation; the suture lines indistinct.
>
> Basal cup projecting laterally in form of a rim; its lower face slightly excavated for the reception of a large stem. Radials about one-third longer than wide, a little wider at the top than at the bottom; facets for the reception of the costals about two-thirds the width of the plates; semicircular, and somewhat thickened at the lower margin; the limbs but slightly truncated. Costals two, forming a syzygy, the lines of union ob-

scure; the hypozygal joints very short and subquadrangular, the epizygal, of which the lower part is placed within the facet, considerably longer and pentangular. Arms ten; stout, cylindrical, composed throughout of rather long, single joints, of which the upper and lower faces are parallel; the main trunks giving off armlets, one from each fifth or sixth joint, the intervening joints pinnule-bearing. The armlets extend to the same height as the main arms, but have only half their width. Both are composed of quadrangular joints, which are somewhat shorter than wide; while the pinnules are short, and their joints fully twice as long as wide. Armlets and pinnules are borne only on one side of the arms: in the anterior ray from the inner side, in the lateral rays from the outer one. There is but one interbrachial plate, but this was apparently followed by several rows of small, nodose, interambulacral pieces. Form and position of anus unknown. Column round; the nodal joints considerably widest, and distinctly rounded at their edges."—Wachsmuth and Springer, 1897.

Remarks.—No additional specimens of this species have been found so far as known. The type is in the Davenport Academy of Science. Owen[44] mentions finding four crushed specimens of a *Hexacrinus* in an encrinal layer about fifty feet above the river in Le Claire's quarry at Davenport. This is the same quarry, according to Barris,[45] at which the type specimen was collected. The type is firmly attached by one side to the matrix and the arms and pinnules are in place. The latter, as noted above, are given off only on one side of the arms while in ordinary crinoids they "are arranged alternately on opposite sides from every second joint." (Crin. Cam. N.A., I, p. 81.) The only American species of this genus occurring beyond Iowa is *Hexacrinus leai* (Lyon) from the Hamilton at Louisville, Kentucky.

Position and locality.—Cedar Valley, "*Spirifer pennatus*" beds, Le Claire's quarry, Davenport, Iowa.

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44 Geol. Surv. Wisconsin, Iowa, Minnesota, pp. 507 and 625; 1852.
45 Proc. Davenport Acad. Sci., vol. VII, p. 20; 1899.

HEXACRINUS SPRINGERI n. s.

Plate XLII, figs. 2-9; plate XLIII, figs. 1-9.

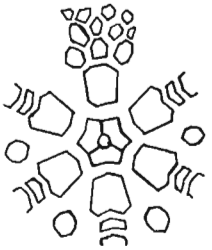

FIG. 72.—Plan of *Hexacrinus springeri*.

Calyx medium size. Cup higher than wide, base truncate and a little excavate; sides gently convex except the left which is flattened in the type, expanding gradually upward but rather abruptly in passing from the basal to the radial cycle; the plates thick and unornamented; the suture lines at bottom of distinct and deep grooves.

BB projecting below in a distinct rim which is only slightly notched by the prominent interbasal sutures; plates not anchylosed. RR longer than wide and a little wider above than below; surface of each plate elevated medially into a broad indefinite ridge which continues up over the IBr; facet for receiving IBr_1 broadly curved and the distal edge thickened at the center of the plate; limbs short and sloping downward. Anal plate with subparallel sides, flatter than the RR, followed by 3, 4, and 4 polygonal pieces, those of the first row about as large as iBr of the other interradial areas. IBr, two, the first quadrangular, a little more than twice as wide as long and extending the full width of the facet, the second pentagonal, distinctly separated by a suture and not forming a syzygy; IIBr small, quadrate, in contact laterally; iBr_1 fairly large, at least eight-sided and apparently followed by two pieces in next range. Arms two to each ray, apparently uniserial; dome and anus unknown. Stem facet round, opening through the basals 1.5 millimeters in diameter.

Remarks.—It is a pleasure to dedicate this fine species to Doctor Frank Springer whose scholarly treatises on North American crinoids have been sources of information and inspiration to every student of this fascinating class.

The type specimen is 13.8 millimeters high from the base to the top of IBr_2 of the left anterior ray; antero-posterior diameter at top of radials 13.6 millimeters. Separate plates of this species are common at the horizon in which the type was found. Several of the plates, while identical with those of the type, in-

dicate that they belonged to individuals of considerably greater size. The type was collected by Mr. C. H. Belanski, and is in the University collection.

Position and localities.—In the Shell Rock limestone on the left bank of Shell Rock river in Floyd county, in the northwest quarter of the northeast quarter, section 4, township 95 north, range 18 west. The *Hexacrinus* zone is only a few feet above the level of the river and can be traced more or less continuously north to Nora Springs and south to Rockford. Separate plates as noted above have been found at several outcrops along the river.

Hexacrinus iowensis n. s.
Plate XLII, figs. 10-13.

A small species, represented in the collections by two calyces which preserve only the BB and RR. Cup expanding gradually, width at top of RR greater than the height at this level; base truncate, flattened or but slightly excavate; the plates fairly thick and ornamented; suture lines distinct and at bottoms of shallow grooves.

BB three, projecting below to form a sharp rim which is slightly notched by the interbasal sutures. In one of the two specimens one of the BB is much larger than either of the other two, is six-sided and supports two RR and on its shoulders half the base of the RR lateral to these; the other two BB are four- and five-sided. In the other specimen the three BB are of nearly equal size. RR a little wider above than below, their sides subparallel, width to length variable, some longer, some shorter than greatest width; IBr facets rounded, shallow, and thickened at the center of the margin. Plates above RR unknown. Column facet round, small; opening through base very narrow.

The ornamentation consists of a number of low ridges or rows of nodes which are parallel to the upper edges and shoulders of the BB, and to the lower edges and sides of some of the RR. In addition low nodes are indiscriminately scattered over the surface of each plate.

The specimen with the normal Hexacrinid base is made the

type. On this the ornamentation which parallels the sutures is the dominant type and though nodes are present they are not as prominent as on the specimen with the irregular base. Type and cotype are in the University collection.

Remarks.—This species is the first American representative of the genus in the Devonian whose plates are ornamented. Complete calyces are awaited with interest.

Position and locality.—This interesting little species was collected by Mr. C. H. Belanski at a small outcrop in the Shell Rock limestone in a gutter along the wagon road on the east side of Shell Rock river in Floyd county. The precise locality is in the southwest quarter of the northwest quarter of section 28, township 96 north, range 18 west. Separate plates also occur at this horizon at several points for some miles up and down the river. Though occurring with *H. springeri* the separate plates are readily distinguished since those of *H. iowensis* are ornamented.

ARTHRACANTHA MAMELONIFERA n. s.
Plate XLII, figs. 14-18.

Species known only from incomplete plates which bear the tubercles characteristic of this genus. One plate, a radial, is the most perfect. Its upper face bears the curved facet for the reception of the IBr; the center of the facet protrudes outward as a thin lip, and its floor slopes inward; the limbs are short. About a millimeter of the upper margin of the plate is thin, nontuberculate, and depressed; below this area the surface is abruptly elevated—mostly so along the mid-line—and the plate is thicker. On this shoulder the tubercles are more or less crowded and irregularly arranged but become fewer and farther apart proximally. Each tubercle closely resembles those on small echinoid plates: at the top is a circular foramen-like pit which served as a socket for the movable spine; around the pit is a mamelon-like border and in many cases the "neck" of the "mamelon" is slightly undercut. The largest tubercles are those toward the center of the plate. These are from one to one and a quarter millimeters in diameter, while the average tubercle is a little over half this and the average height is close

to one-half millimeter. Sixteen tubercles are present on the plate and doubtless a few are missing along with the proximal border which is broken off.

Among the tubercles and even on their sides are small granules and a strong lens will show among these still another series decidedly smaller and finer and quite numerous. The inner surface of the plate is smooth and concave.

Remarks.—Careful screening of the shale in which the plates are found has not yielded any undoubted spines. It is thought that the spines were much larger and coarser than those of any described species of *Arthracantha.* Incomplete plates have been found at three localities. At each of these there occur abundant segments of a small round stem with a small lumen, but since a flexible crinoid occurs in the same bed it is not certain that the stem segments are to be associated with *Arthracantha.* It should be noted that this is the first western occurrence of this genus—all its species heretofore having been found in the vicinity of Lake Erie.

The writer wishes to thank Miss Winifred Goldring of the New York State Museum at Albany for identifying these plates as those of *Arthracantha.* Miss Goldring's forthcoming monograph on the Devonian Crinoids of New York contains many interesting species of this genus.

Position and localities.—Independence shales near the base of the Iowa Devonian section at exposures numbers one and three near Brandon, Iowa[46], where they were collected by Merrill A. Stainbrook and the author. A tray of unidentified specimens collected by Calvin[47] in the late seventies at Independence in shales of the same age as at Brandon contains one imperfect plate which is unhesitatingly referred to this species.

FLEXIBILIA Zittel

An order of dicyclic crinoids with a flexible dome and with freedom of the radial series above the lower brachials; infrabasals three, unequal. Plates thick, often short; arms uniserial and non-pinnulate. Tegmen flexible, with the roofed ambulacra

[46] Proc. Iowa Acad. Sci., vol. XXVI, pp. 485-491, 1919; also, Iowa Geol. Surv., vol. XXVII, pp. 387-399.

[47] Bull. U. S. Geol. and Geog. Surv., vol. IV, No. 3, pp. 725-730; 1878.

exposed. Stem always round. The order is strictly Paleozoic extending from the Ordovician to the Pennsylvanian (Des Moines) of Europe and America. Recently Doctor Wanner of Bonn has described some remarkable representatives of this order from the Permian of the Island of Timor, Dutch East Indies. This greatly extends the time range as well as the geographical distribution of the order.

ICHTHYOCRINIDAE Wachsmuth and Springer

Infrabasals horizontal, not appearing exteriorly and taking no part in the calyx wall (except in *Clidochirus*). Crown elongate or rotund. Rays widening upward to accommodate the expansion of the calyx. Three of the ten genera of this family occur in the Iowa Devonian.

CLIDOCHIRUS IOWENSIS n. s.

Plate XLII, figs. 19-34; plate XLIII, figs. 10-44.

Perfectly preserved plates and united IBB belonging, it is thought, to this genus, occur abundantly at certain horizons in the marly shales of the Lime Creek beds. The more easily identified parts are radials, primibrachs, and infrabasals. IBB three, two of them five-sided, the other four-sided; outline pentagonal, extending well beyond the column, plates turned upward distally and forming a part of the cup; sutures distinct. Column facet flat, surrounded by a definite rim; lumen small, quinquelobate, its angles radial in position; viewed from within the axial canal is seen to project upward above the calyx floor, its rim forming a roughly trilobate funnel—the lobes over the five-sided IBB being wider than the single lobe over the three-sided plate; between the lobes of the funnel and the floor of the calyx are several supporting ridges, two or three on the larger plates and but one (or two) on the small plate; these ridges extend distally reaching quite to the edge of the plate in some cases. Within, the funnel is channeled, its grooves being limited by their septa which continue downward to form the reentrant angles in the quinquelobate lumen; the channels pass directly downward and without torsion. The funnel, just described, was the seat of the chambered organ, the chief nerve

center of the crinoid and the downwardly extended grooves are the paths of the five axial nerve cords. The distal faces of the IBB plates have deep pits or fossae, and sharp ridges limit those portions of the edge of the infrabasal circlet which opposed the proximal face of each of the five basals. BB large, curved, not in contact with the stem, polygonal; one or two, which are larger and heptagonal, are thought to be examples of the modified posterior basal which supports the anal series. RR pentagonal, wider than long, thicker than BB, distal face showing articulating ridge and groove. One or two thick, irregular, many sided plates are set aside as anal pieces. IBr_1 thick, three to four times as wide as long; IBr_2 pentagonal, axillary; besides these occur pieces which are evidently IIBr and higher orders.

Surface of plates of lower cup smooth; the RR are finely granular and succeeding plates are more so.

Remarks.—The radials and brachials of this species might well be compared with those of *Lecanocrinus*. Indeed in some former notes the writer referred them with some doubt to that genus[48]. Since then close search has resulted in finding several specimens of the united IBB which show that they are large and protuberant as in most of the species of *Clidochirus* and are not concealed by the stem as in all known Devonian species of the former genus. Similarly they may be compared with those of *Ichthyocrinus* but again the large IBB are markedly different from the hidden and often resorbed IBB of that genus.

The fine development of the funnel in this species illustrates well the features of that interesting anatomical structure. In the description given above the writer has drawn freely on Doctor Springer's excellent elucidation of it in his recent work on the flexible crinoids.

This species of *Clidochirus* extends the range of the genus into the Upper Devonian although a doubtful successor is known from the Mississippian of Kentucky.

Position and Localities.—In the upper part of the fossiliferous marly shale of the Lime Creek beds; found at several local-

48 Bull. G. S. A., vol. 31, p. 212, 1920.

ities on the high hills just west of Rockford and at Bird Hill and vicinity.

CLIDOCHIRUS (?) MAXIMUS n. s.
Plate XLII, figs. 35-37.

A very large, thick axillary IBr is tentatively referred to this genus. The surface of the plate is strongly arched in the direction of its width and is gently curved longitudinally. The proximal and distal faces show well the articulating ridges and grooves. Lateral faces smooth, that on right covering but about two-thirds of the extremity, the other third is rounded, distal in position, and evidently not in contact, suggesting that the plate probably belongs in the left posterior ray, in the lower part of which ray contact is lacking in this genus. Surface marked by numerous small and evenly distributed granules.

Length of plate at middle 7.7 millimeters, greatest width 16.0 millimeters, greatest thickness 7.5 millimeters.

Remarks.—This solitary plate from the Independence shale is the only bit of crinoid found in that limited formation except the plates of *Arthracantha mamelonifera* described earlier in this paper and some stem segments. The unusual proportions of the plate suggest the specific name *maximus* which is offered for convenience in faunal lists and references.

Position and localities.—Independence shale, at exposure number two[49] near Brandon, Iowa. Collected by the author.

EURYOCRINUS BARRISI Springer.
Plate XLIV, fig. 8; plate XLV, fig. 12.

1920. *Euryocrinus barrisi* Springer. Crinoidea Flexibilia, p. 316. Plate 40, figs. 1-3.

> "A large species, with elongate crown; broadly truncate and excavate at the base; height, 50 mm.; width at IIIBr, 24 mm.; base, 10 mm. Calyx with nearly straight sides, spreading from outside of basal rim to top of IAx, 1 to 1.5. Cross-section at first bifurcation sharply pentagonal. Arms closely abutting to third axillary, with a more or less angular median elevation,

[49]Proc. Iowa Acad. Sci., vol. 26, p. 487.

and raised winged buttresses at sides of brachials; they are broad below, tapering rapidly with rather short divisions to four bifurcations, beyond which they are more rounded and divergent. Sutures arcuate. Base broadly and shallowly concave. iBr few, spaces narrow with the rays meeting above them. Surface smooth, except for the angularities and marginal elevation of the brachials.

IBB rather large for this family, but entirely within BB, and not filling the column facet. BB large, forming the greater part of the basal rim, and visible in side view as good-sized elongate triangles; post. B narrow and very elongate, nearly as high as RR, followed by one anal plate with a few others succeeding in one principal series and some smaller plates at the side. IBr 1, moderately large, angular, with one or two smaller ones following in large specimens; arched over by the winglike projection of the axillaries; iIIBr sometimes present. RR large, wider than succeeding IBr, their lower angles curving into the basal cavity. IBr 3 short and wide, increasing in width to the axillaries. IIBr 3. IIIBr 4 or 5 inner, and 8 or 10 outer; plates of these series as well as the upper two IBr very short and wide, meeting and interlocking laterally by angular margins, with a prominent node or ridge at the angles. All higher brachials very short and wide. Column large, with excavate facet less than diameter of basal rim; tapering slowly from the calyx and gradually changing from short to longer and alternating columnals."—After Springer.

Remarks.—The original illustration of this fine species from Buffalo is here reproduced with the permission of Doctor Springer. A much broken and incomplete calyx found in one of the ravines below Davenport is referred with some doubt to this species. The plates are smooth but some of them show the angularities characteristic of *E. barrisi.* It was collected by Rev. U. A. Hauber and kindly given the author for study. In the Springer collection are two from Partridge Point, near Alpena, Michigan, collected by Barris, in whose honor the species was named.

Position and locality.—Cedar Valley beds at Buffalo, Iowa. Also in the Devonian, Traverse group, Alpena, Michigan.

Dactylocrinus Quenstedt.

Infrabasals wholly within the basals and concealed by the column. Rays above the radials separated by a single interbrachial but in contact for some distance above this plate. Posterior radials separated by a single anal plate followed by one (or two) small plates in series. No radianal. Arms heterotomous; IBr two, IIBr three, IIIBr three (or more).

Dactylocrinus stellatimbasalis n. s.

Plate XLIV, figs. 1-5.

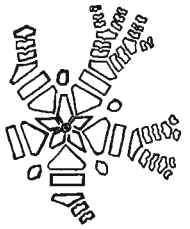

Fig. 73.—Analysis of the calyx of *Dactylocrinus stellatimbasalis*. The left anterior ray is incomplete beyond the first primibrach.

Description based on a single specimen with a nearly perfect calyx—the holotype.

Body small, sides broadly rounded, right and left posterior and right anterior rays partly preserved; a number of the plates of the other two arms are jumbled together over the tegminal region. Calyx slightly deformed by compression and as a result the right and left diameter at the top of the RR is 7.7 millimeters, while the antero-posterior diameter at the same level is 8.5 millimeters; height of calyx to top of RR about 3 millimeters, to top of $IIBr_3$ 7.5 millimeters. IBB unknown.

BB five, proximal part of each bent abruptly inward and upward to form the basal concavity; proximal edges concealed; apparently pentagonal except the posterior basal which is hexagonal. The distal edges of each basal beginning with the posterior plate and proceeding to the right would make, if produced, angles of about 35, 61, 44, 55, and 50 degrees respectively. Viewed basally the five plates strikingly resemble a five-pointed star.

RR large, wider than high, hexagonal or heptagonal, each plate pointed proximally and resting in the broad angle between two points of the basal star. RR in contact all around except on the posterior side where they are separated by the anal plate.

IBr two, the first of which is elongated quadrangular being about three times as wide as high; the second or axillary is pentangular. IIBr three; IIIBr three in place—plates beyond

these not in position. The plates of each ray are in contact laterally with those of the adjacent rays except for a single small hexagonal or heptagonal iBr which is situated between the IBr and extends down for a short distance between the distal corners of the RR. Between the left anterior and left posterior rays the iBr is missing, evidently having been crowded out when the specimen was compressed as mentioned above. In the posterior iBr area a heptagonal anal plate rests on the truncated apex of the basal separating the RR and the quadrangular IBr of the posterior rays. Above the anal plate is a small vacant space from which, judging from the surrounding facets, apparently one or two small plates have been lost; the adjacent IBr and IAx of the left posterior ray are slightly skewed out of their natural position. This accident, it seems, loosened the small plate (or plates) and permitted them to drop out. The missing iBr, mentioned above, was at the opposite side of the displaced IAx of the left posterior ray.

Column small, round, 1.8 millimeters in diameter; a few thin columnals preserved in the depressed base; central perforation minute, obscurely five-sided; depth of basal depression, as exposed along the stem, 1.2 millimeters.

Surface of the BB and RR smooth; IBr and iBr granular, the granulations increasing in prominence on the plates distal to these. Sutures distinct, flush with the surface, those between the brachials characteristically arcuate as in many of the Flexibilia.

Remarks.—This delicate and rare species is to be compared with *D. concavus* (Rowley) of the Craghead Creek shale of the Devonian of Missouri which is larger, more rotund, and has a broader base than ours; moreover the plates of the Missouri species are all smooth. Two figures of Rowley's type are included in the plate for comparison—for these the writer has to thank Doctor Springer. It is a matter of keen regret to the author that the Iowa species did not get into the hands of the author of the Crinoidea Flexibilia in time to appear in that great work. Only seven species, including *D. stellatimbasalis,* of this genus are known. Three of these occur in the European Devonian, as follows: one from the Upper Devonian of Russia,

one from the Upper Devonian of Belgium, and one from the Middle Devonian of the Eifel, Germany. The American species are from the central part of the United States, namely in Missouri, in Iowa, and at Alpena, Michigan, in Devonian beds of approximately the same age; the fourth is a doubtful species and comes from the Mississippian (Waverly) beds near Richfield, Ohio.

Position and locality.—In the marly shales of the Lime Creek beds of Cerro Gordo county in the southeast quarter of section 13, township 95 north, range 19 west, near the top of the beds. It was collected by Mr. C. H. Belanski.

TAXOCRINIDAE Wachsmuth emend. Springer

Flexible crinoids in which the posterior interradius is always differentiated and occupied by anal plates in a tubelike series and not incorporated in the calyx. Rays above the radials partly or wholly separated all around. Crown in most cases elongate. They extend from the Ordovician to the Mississippian; three genera and eleven species are known from the American Devonian, eight additional Devonian species are found in Europe. Two species have been reported from the Iowa Devonian, the type of neither of which has been seen.

EUTAXOCRINUS GRACILIS (Meek and Worthen).

Plate XLIV, figs. 17, 18.

1865. *Taxocrinus gracilis* M. and W. Proc. Acad. Nat. Sci. Phila., vol. XVII, pp. 142, 143.

1866. *Rhodocrinus* (*Taxocrinus*) *gracilis* Shumard. Trans. Acad. Sci. St. Louis, vol. II, p. 397.

1868. *Taxocrinus gracilis* M. and W. Geol. Surv. Ill., vol. III, p. 421, text fig., and Pl. 13, fig. 3.

1879. *Taxocrinus gracilis* W. and Sp. Rev. Paleocr., I., p. 48.

1920. *Eutaxocrinus gracilis* Springer. Crinoidea Flexibilia, p. 367, Pl. XLIX, figs. 8a, 8b.

> "Body small, expanding moderately from the base. Basal pieces small, and looking like the last joint of the column divided into three pieces; subradial pieces so small and narrow as to allow the lower middle ex-

tremity of the first radials to come nearly, or in some instances, quite down upon the basal pieces; four of them triangular and more or less wedge-shaped so as to project up between the first radials as much as half the length of the latter; the fifth one larger than the others, but slightly tapering, and truncated above by the anal? piece, so as to present a quadrangular or subpentagonal outline. First radial pieces considerably larger than the subradial, of nearly equal length and breadth, or a little wider than long, hexagonal in form, the inferior sloping, and upper horizontal sides much larger than the others. Second radials, in four of the rays, shorter than the first, wider than long, and generally hexagonal; in the fifth ray of the specimen under investigation, the second piece has its right margin enormously, and perhaps abnormally, developed, and extended obliquely upwards, so as to fill the whole interradial space above the comparatively minute interradial piece, quite as far as the second bifurcation of the rays, with one solid plate. In the ray containing this singularly developed second piece, there are two other primary radial pieces succeeding it, of near the natural size and form, upon the last (fourth) one of which the first bifurcation takes place; after this each of the divisions bifurcates again on the fourth piece, and the two inner subdivisions again on the fourth piece, while the two outer ones send off subdivisions, one on the sixth, and one on the seventh piece. In the ray immediately to the right of that just described, and apparently the anterior one, no division takes place until upon the eighth piece, all the pieces between the second and eighth being transversely oblong or about twice as wide as long, and gradually diminishing in size. In the other three rays, the first division takes place on the third piece, and the second and third divisions also on the third piece, the arms rather rapidly diminishing in size with each bifurcation.

Interradial pieces very small, rather longer than wide, somewhat wedge-shaped above, and resting between the short superior lateral sloping sides of the first radials, and supporting on each superior sloping side a short truncated margin of the contiguous second radials, which generally meet over the little interradial, so as to isolate it from the free space above, though

not always. Anal piece a little larger than the interradials, hexagonal in form, and resting with one short side upon a truncated upper side of the largest subradial; while it connects on the right with a first and second primary radial, and on the left with a second and third primary radial, and one first secondary radial.

Surface of body apparently smooth, but showing granules on some of the divisions of arms. Patelliform accessory pieces not developed between the primary radial pieces, but quite distinct between some of the secondary. Column, as in other species of the group, round and tapering downwards from the base, near which it is composed of very thin pieces."—After Meek and Worthen, 1865.

This species was described from an abnormal specimen. However, Springer gives it as his opinion that "it is probably a good species representing the genus in the western Hamilton" just as for example *E. whiteavesi* represents it in the eastern Hamilton. The writer has collected imperfect fragments of what is apparently a Taxocrinid in the Buffalo region but no material of specific value and that found may belong to the next species.

The type specimen is in the University of Illinois and the matter of its geological horizon and locality is somewhat confused. In the original description Meek and Worthen list it from the "Hamilton at New Buffalo, Iowa", and compare it with *Taxocrinus interscapularis* Hall, "from the same locality". In Shumard's catalog, listed above, New Buffalo is likewise given as the locality. In the republication of the species in volume III, Illinois Geological Survey, the authors again compare it with *T. interscapularis* "from the same locality" but cite locality and position "Same as the last" which is *Microcyclus discus* from the Hamilton of Jackson county, Illinois, where occurs an entirely different Devonian basin and quite remote from the area about (New) Buffalo. Wachsmuth and Springer in Revision Paleocrinoidea list it from Devonian of Jackson county and again in the Crinoidea Flexibilia Springer gives the Jackson county reference. Barris[50] includes

50Proc. Davenport Acad. Sci., vol. 7, p. 27, 1899.

the species in his list of the rarer fossils of the *Spirifer pennatus* beds of the vicinity of Davenport.

Dr. T. E. Savage of the University of Illinois, to whom the author submitted the discrepancy, says "the label on each of these types (*T. interscapularis* and *E. gracilis*) states New Buffalo, Iowa, as the locality from which they came. I assume the Illinois Report was in error in stating locality in such a way as to indicate Jackson Co., Illinois".[51] In view of these facts the author is convinced that the original specimen was collected in the Devonian beds near Buffalo.

In Barris' list just mentioned is included also *Taxocrinus nuntius,* now known as *Synaptocrinus nuntius* (Crin. Flex., p. 302). To the writer this is the only known reference to a western occurrence of this species. Barris' identification is probably incorrect and may be regarded as an effort on his part to identify the imperfect Taxocrinid material which he found at and near Davenport.

TAXOCRINUS INTERSCAPULARIS Hall.
Plate XLIV, fig. 10.

1858. *Taxocrinus interscapularis* Hall. Geol. Surv. Iowa, I, pt. 2, p. 482, pl. 1, fig. 3.

1879. *Taxocrinus interscapularis* W. and Sp. Rev. Paleocrin., I, p. 48.

1920. *Taxocrinus interscapularis* Springer. Crinoidea Flexibilia, p. 385, pl. LII, fig. 6.

Not *Taxocrinus interscapularis* Cleland. Wis. Geol. Surv. Bull. 21, p. 42, pl. 3, figs. 11, 12, 1911.

"This species is only known by a single specimen, and that is in such an imperfect condition that no satisfactory detailed description can be made from it. One side is imbedded in a hard matrix, and the exposed part is much injured by weathering and accident; the base is broken off, and the basal plates described by Hall are part of the radials, according to the interpretation by my artist; it apparently has 3 IBr instead of 2, as would follow from the original description. There are two peculiar things about the

[51] Personal communication, March, 1923.

specimen: (1) the high location of the iBr, supported by the IBr_2, instead of R as in other cases; (2) that the inner division of the IIIBr is longer than the outer. There is also a tendency in the brachials to coalesce for two or three ranges above the axillaries, which is not seen elsewhere in this genus. The species is apparently well-marked by these characters, but its relations remain obscure; and it may even not belong to this genus, as the anal side is unknown."—After Springer, 1920.

Position and locality.—Lower part of Cedar Valley limestone in vicinity of Buffalo, Iowa. The type is in the University of Illinois.

INADUNATA Wachsmuth and Springer

An order of crinoids which are monocyclic with a few families dicyclic. Plates of the cup firmly united. Calyx includes the basals (and infrabasals when present), radials, and anal plates. Brachials never form a part of the cup. Arms may be pinnulate or non-pinnulate, biserial or uniserial. Range, Ordovician to Triassic.

SYNBATHOCRINIDAE Wachsmuth and Springer

Small monocyclic crinoids with five basals in the primitive forms but only three unequal basals in the later genera; radials five. Long anal tube. Arms five, simple; column round.

SYNBATHOCRINUS MATUTINUS Hall.

Plate XLIV, fig. 9.

1858. *Synbathocrinus matutinus* Hall. Geol. Surv. Iowa, vol I, pt. 2, p. 483, pl. 1, fig. 2.

1885. *Symbathocrinus matutinus* W. and Sp. Rev. Paleocr., pt. III, p. 169.

1923. *Synbathocrinus matutinus* Springer. Smith. Misc. Coll., vol. 76, no. 3, p. 29.

"Basal plates undivided, forming a slightly projecting disc in the specimen: first radial plates wider than long; second radials longer than wide, obtusely angular along the centre; brachial plates quadrangu-

lar, and subangular longitudinally along the centre: column round, composed near the base of alternating larger and smaller rings.

The only specimen seen is a fragment, imperfect at the upper extremity, with the surface much broken, and particularly the basal and first radial plates, while the surface of the arm-plates has been exfoliated. The structure, therefore, is not very satisfactorily determined, though the peculiar form of the crinoid and the succession and arrangement of the plates are sufficient to distinguish it from any other established genus of crinoids."—After Hall, 1858.

No additional specimens of this rather obscure species have been collected so far as known.

Position and locality.—Cedar Valley shaly limestone in "*Stropheodonta demissa* bed," near Buffalo, Iowa, and in Michigan.

CREMACRINIDAE Ulrich

Crinoids with monocyclic, asymmetric calyces due to the bending of the stem so that the calyx nodded or turned permanently downward; as a result the plates are shifted from their conventional positions to new ones. BB on posterior side of calyx and connecting with the RR of the anterior side by a flexible articulation. Arms three or four.

DELTACRINUS BARRISI (Worthen).

Plate XLIV, figs. 20, 21.

1875. *Calceocrinus barrisi* Worthen. Geol. Surv. Ill., vol. VI, p. 510, text fig.

1885. *Calceocrinus barrisi* W. and Sp. Rev. Paleocr., III, pp. 276, 281.

1893. *Calceocrinus barrisi* Bather. Crin. of Gotland, pt. 1, p. 66 (in a list).

"Body above the medium size and composed of thick massive plates. Lower dorsal plate triangular and about three times as wide as high. Upper dorsal plate less than half the size of the lower, and triangular in outline. Dorso-lateral pieces presenting an irregular pentagonal outline, with abruptly rounding lateral

sides, and projecting upper angles. Arms and column unknown.

This species may be readily distinguished from any other known to us by its thick massive plates and robust appearance."—After Worthen, 1875.

Remarks.—The type specimen has not been seen but in the Davenport Academy collection there is a part of a specimen composed of three plates, showing stem facet and an articulating face. Its plates are delicately granular. It is assumed to belong to this species.

Position and locality.—In the Phragmoceras zone[52] of the Upper Davenport beds[53], Davenport, Iowa. The Davenport Academy specimen comes from Cook's Quarry, Davenport, and was collected by Professor W. H. Pratt. Barris lists the species as coming also from the Devonian of the Rock Island and Moline area in Illinois[54].

CYATHOCRINIDAE Roemer

Dicyclic crinoids with a heavy tegmen; anus passing through the side of the cup as in *Gasterocoma,* through the tegmen as in *Carabocrinus,* or at the end of a tube as in *Cyathocrinus.* Arms non-pinnulate. Radial facets semicircular and narrower than the width of the radial. Infrabasals usually five. Stem in most cases round.

CYATHOCRINUS ROCKFORDENSIS n. s.
Plate XLIV, figs. 11-16.

Radials bearing the horse-shoe shaped facets characteristic of this genus are fairly common at certain zones in the marly shales of the Lime Creek beds. The plates are sub-pentagonal, smooth, quite thick, and their sides are nearly parallel; the facet is directed upward and outward and is bordered by a sharply raised rim; the notch at its inner edge for reception of the ambulacral groove is rounded and fairly deep; the two proximal side-faces meet in a sharp point. An average radial is about 7.5 millimeters wide and close to 6.8 millimeters in

52Proc. Davenport Acad. Sci., vol. VII, pp. 17, 18 (Barris); 1899.
53Geol. Surv. Iowa, vol. IX, p. 451, 1899 (Norton).
54Proc. Davenport Acad. Sci., vol. II, p. 267, 1878.

length. Several plates which may be basals, and others which may be brachials, occur with these radials but since the loose plates of *Clidochirus iowensis* are also found at practically the same horizon it is not practical to assign them with certainty to either of the two genera since they are not so characteristically marked as are the radials of *Cyathocrinus* and the radials and primibrachs of *Clidochirus*.

Position and localities.—In the marly zone of the Lime Creek shales near its top at Bird Hill and vicinity and at the outcrops west of the Rockford Brick and Tile plant, Rockford.

POTERIOCRINIDAE Roemer

Dicyclic crinoids with tegmen of undifferentiated plates often swollen into a ventral sac; arms pinnulate, usually dichotomous. Infrabasals five (or three), frequently coalesced. Devonian to Permian.

Poteriocrinus buffaloensis Worthen.

Plate XLIV, fig. 19.

1890. *Poteriocrinus buffaloënsis* Worthen. Geol. Surv. Ill., vol. VIII, p. 89, pl. 12, fig. 1.

> "Calyx small, obconic below the summit of the radial plates, or about once and a half as wide as high. Basals small, pointed above, forming a low pentagonal cup.
>
> Radials two on each of the two rays visible, the first pentagonal wider than high; the second quadrangular and about twice as wide as high.
>
> Brachials pentagonal, wider than high, pointed above, and supporting on their upper sloping sides the first arm plates.
>
> Arms two to each of the rays visible, composed of rather stout joints that are longer than wide, and project slightly at their upper margins where they support stout pinnules.
>
> Anal series unknown.
>
> Column rather stout where it joins the body, composed of slightly projecting plates that diminish gradually in size below."—After Worthen, 1890.

The only specimen known to the author is in the Worthen collection at the University of Illinois.

Position and locality.—Cedar Valley limestone, near Buffalo, Iowa.

Decadocrinus vintonensis n. s.
Plate XLV, fig. 1.

A single flattened specimen firmly attached by one side to the matrix is made the basis of this species. The arms are fairly well preserved and a part of the proximal portion of the stem remains.

Calyx small, base apparently flat, sides expanding gradually but the cup is not spacious; plates smooth. Arms long, dichotomous, the two parts strictly equal; joints of arms thicken distally especially those joints which give rise to the pinnules—this feature gives the arms a knotted appearance. Pinnules fairly strong and all turn abruptly upward. Six arm divisions, or the equivalent of three arms, are on the exposed surface. The right posterior arm shows both divisions; between it and the left posterior couplet a series of plates rises up and tapers to a point five millimeters above the dichotom. These plates are interpreted as the base of the ventral sac on the posterior side.

Stem round, tapering distally, about fourteen columnals in five millimeters which is the length of the part preserved; height of calyx to the arm bifurcation, 7.5 millimeters, length of entire crown, 42 millimeters.

Remarks.—This specimen now in the Calvin collection was collected many years ago at Vinton by Mr. E. P. Whipple. Calvin submitted it to Dr. Frank Springer who labelled it "*Decadocrinus,* undescribed species, F. S." This generic determination has been followed in this paper.

Position and locality.—Devonian, exact horizon unknown, near Vinton, Iowa.

ECHINOIDEA Bronn
The Sea Urchins

This class of echinoderms has had a long history and their remains are known from Ordovician to Recent times. Their Paleozoic history previous to the Mississippian is quite meager

there being according to Jackson (Phylogeny of the Echini, p. 236; 1912) but three Ordovician species, all from Russia; four Silurian species, three from England and one from the Niagara group in New York; and from the Devonian five genera and ten species. Of the latter only one species is described from America, seven come from Germany, and two from England. In the same year Olsson[55] described a new genus and species, *Lepidechinoides ithacensis,* from the Upper Devonian at Ithaca, New York. This made only two genera represented by one species each in the American Devonian up to the time the writer reported three additional genera from Iowa.[56]

The Iowa material is composed largely of loose plates, spines, and parts of the lantern, all very well preserved, but its dissociated condition leaves us somewhat in ignorance as to the characters of the complete tests. A part of an interambulacrum of *Nortonechinus,* found at Rockford, does aid materially in the interpretation of that genus. However, the mode of imbrication and the position and relation of the spines had been determined before the fragment of the test was obtained. Of *Xenocidaris,* specimens only of the slender-shafted spines, a hemipyramid, and one doubtful plate have been collected; due to the general similarity of the spines of the two genera both are placed in the same family in this paper. *Devonocidaris* is plentifully represented by a rather full complement of all the parts, belonging, however, to dismembered and fragile tests. The characters of its plates, as pointed out later, consign it, in the writer's opinion, to a different family. All three genera are placed in the order Perischoëchinoida, a brief diagnosis of which, as well as of the families involved, is given below. In these diagnoses the work of Jackson is closely followed.

PERISCHOËCHINOIDA M'Coy

Echinoids with regular tests in which the periproct is within the oculo-genital ring; usually spheroidal in shape. Ambulacral areas with two to twenty columns of plates, all simple and

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55 Amer. Jour. Sci., 4th ser., vol. 33, pp. 442-446, 1 fig.; 1912.
56 Bull. Geol. Soc. Amer., vol. 31, p. 212; 1920.

bearing one pore-pair each. Interambulacra with three to fourteen columns of plates. With few exceptions the plates of the adambulacral columns are pentagonal, and those of the median columns hexagonal. Plates thick or thin, and bearing primary perforate tubercles and spines with secondaries, or secondaries only. Plates of the test may or may not be imbricate. Interambulacrals, when imbricate, do so aborally and from the center laterally and over the adjacent ambulacral plates. Genitals have three to many genital pores. The lantern is inclined and composed of forty pieces. Teeth grooved, pyramids wide-angled, foramen magnum moderately deep, epiphyses narrow, capping the half-pyramids; brace and compass as in modern echinoids.

ARCHEOCIDARIDAE M'Coy

Test spheroidal or depressed; ambulacra narrow, with two columns of plates in each area. Pore-pairs uniserial or slightly biserial. Four to eight columns of plates in each interambulacrum (*Nortonechinus* has at least eleven, possibly twelve or fourteen, rows) more or less imbricating aborally. Interambulacral plates bear a large central perforate primary tubercle and scrobicule; large primary spine, also secondary tubercles and spines. Oculars and genitals unknown or very doubtful.

Nortonechinus Thomas

1920. *Nortonechinus* Thomas. Bull. Geol. Soc. Amer., vol. 31, p. 212; also in Science, n. s., vol. lii, p. 89.

Genus based on a part of a broken test, a large number of dissociated plates and spines, and parts of the lantern. The fragment of the test is a portion of an interambulacral area with a large number of rows of plates which are strongly imbricate aborally.

Ambulacral plates small and thin bearing one pore-pair each; on the inner surface is an articulating hooklike process which aids in the imbrication.

Interambulacral plates fairly thick, rounded pentagonal in outline but the elevated portion within the sutures is polygonal

or rounded polygonal, the number of sides being six, rarely four, or five; plates imbricate, the outer bevel developed adorally into a broad flange which is overlapped by the inner bevel of the next adoral plates. Each plate bears a low, perforate, median tubercle, has a fairly wide scrobicular area and a low basal terrace.

Primary spines greatly expanded distally until on the crowded parts of the test they are rendered polygonal by mutual contact; the base concave, milled ring absent, fine vertical striations, apical face pustulose or slightly spinulose. The development of secondary spines doubtful; a few miliaries.

Parts of jaw-apparatus large and very similar to those of modern species.

The striking features of this genus are the large number of columns in the interambulacra, the greatly modified plates to meet the demands of the excessive imbrication, and the remarkable distal expansion of the primary spines.

This genus seems to be most nearly allied to *Archeocidaris,* a genus not yet reported below the Mississippian, but differs from it in having more columns of interambulacral plates, in having variably polygonal rather than regularly hexagonal (adradials pentagonal) plates, in the far greater development of the imbrication, in having mutually compressed spines, and in the absence of a milled ring on the spine. In fact the large number of columns in each interambulacrum makes reference to the family Archeocidaridae untenable without a redefinition of the family.

The strong imbrication recalls *Eocidaris* of the Devonian of Germany but the presence of a basal terrace and the character of the spines in *Nortonechinus* strongly set it off from that, unfortunately, imperfectly known genus.

A few of the more slender spines of *Nortonechinus,* presumably from the younger parts of the test, terminate in circular or spinulose expansions; these somewhat resemble the club-shaped spines of *Xenocidaris,* elsewhere described in this paper, but this resemblance is more likely a case of parallel adaptation than of close relationship.

The occurrence of expanded appendages is rare in early

echinoids. The feature reached remarkable development and diversity in the cidarid echini, especially during the Mesozoic. Bather in his "Triassic Echinoderms of Bakony" has treated very ably the Bakony genera which show distally enlarged spines. In the Paleozoic such development was heretofore unknown barring the moderate distal expansions of *Xenocidaris* mentioned above. In the modern seas, however, remarkable modifications of the spines occur reaching an extreme in the tessellated spines of *Colobocentrotus atratus* Brandt,[57] which are distally expanded and rendered polygonal by compression very much as were the spines of *Nortonechinus*. (See text figure 79.)

Spines and plates of this remarkable echinoid were collected some years ago by Dr. William Harmon Norton, Professor of Geology, Cornell College, Mount Vernon, Iowa. Doctor Norton very kindly loaned the material for study and the author takes much pleasure in naming the genus in his honor. Since then a considerable quantity of the remains has been added by the writer and others.

Genotype, *Nortonechinus welleri*.

Nortonechinus welleri n. s.

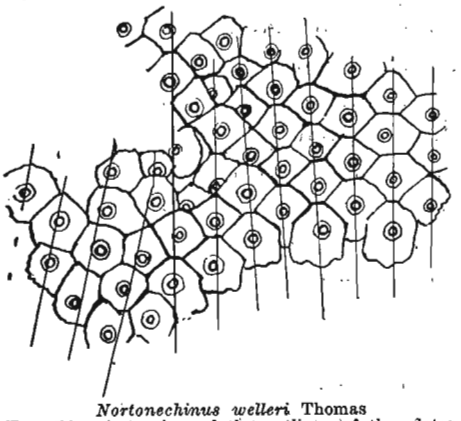
Plates XLVII, figs. 1-7; XLVIII, 1-49; XLIX 1-6 and 8-23.

This interesting echinoid is represented by a part of a test, here made the type, by isolated plates and spines, and by parts of the lantern. The test fragment is a part of an interambulacral area, presumably from near the ambitus. The specimen is approximately five by six centimeters in greatest dimensions and together with the mass of adhering plates, spines and so forth on the interior surface is about one centimeter in thickness.

On the outer surface are fifty-five contiguous plates arranged in natural order except for some distortion and the slipping of a few plates out of line. The inner surface is covered with a jumble of interambulacral and a few ambulacral plates, spines, and parts of the lantern. The bulk of the speci-

57 "A Treatise of Zoology," edited by E. Ray Lankester, Part III, The Echinoderma, p. 314, text figure xxxiv, London, 1900.

men is evidently a conglomerate of this character held together by the soft clayey matrix.



Nortonechinus welleri Thomas

FIG. 74.—A tracing of the outlines of the plates in the type specimen to show the meridional as well as the diagonal arrangement of the rows. The alignment is somewhat imperfect due to partial distortion of the specimen especially in the region of the fourth and fifth rows from the left. Moreover the plates of this area are partly concealed by adhering spines. After figure 7, plate XLVII.

The plates of the natural surface form parts of eleven or possibly twelve meridional rows and illustrate well the strong aboral imbrication. On the upper left hand corner of the specimen (as oriented in the illustrations) is a cluster of eight or ten primary spines held in place by the clay, some of them in positions approximating their original relation to the test; elsewhere over the surface several fine, delicate miliary spines lie attached more or less firmly to the plates. Unfortunately only a few plates remain in the right and in the left rows but those remaining do not appear to be adradials, from which it may be concluded that the ambulacrum had at least thirteen or possibly fourteen rows of plates. The imbrication is of such a character that diagonal rows in either direction are much more apparent than the meridional rows. Referring again to the inner surface it will be found that the confused mass is made up chiefly of interambulacral plates and primary spines; there are also a few miliaries, some ambulacrals standing on edge in a closely packed row, and in one corner is a brace 11.5 mm. in length.

Plates of the interambulacrum thick and strongly imbricate; an average free plate is rounded polygonal or roughly pentagonal in outline and is made up of three areas, the intrascrobicular, the extrascrobicular or intertubercular tract, and the marginal border. An examination of the inner surface of the plate reveals the fact that approximately one-half of it is bevelled obliquely. With this fact in mind the plate may be

oriented according to Duncan's rule[58] that in a meridional series of interambulacral plates the adapical margins are bevelled on their inner surfaces; hence, the broad flange on the plates of this species is an adoral extension which is bevelled on its outer surface and grows thinner toward its margin.

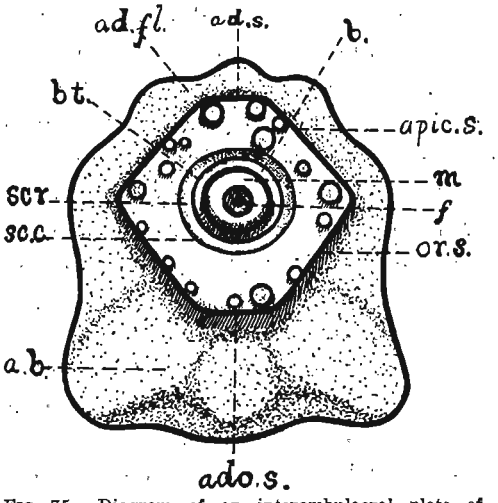


FIG. 75.—Diagram of an interambulacral plate of *Nortonechinus welleri* Thomas to illustrate the terminology used in the text. *sc. c.* scrobicular circle, *scr.* scrobicule, *b. t.* basal terrace, *b.* boss, *m.* mamelon, *f.* foraman, *ad. s.* adapical suture, *apic. s.* apicad-interradial suture, *or. s.* oradinterradial suture, *ado. s.* adoral suture, *a. b.* adoral beyel, *ad. fl.* adapical flange. The area between the scrobicular circle and the sutures is the intertubercular tract; the secondary spine bases on this area form a nearly perfect circle in some echinoids and are called the scrobicular ring. The space within the scrobicular circle is known as the intrascrobicular area. Drawn by *E. Drewelowe Van Ek.*

The intrascrobicular area bears a low-domed mamelon centrally perforated by a round foramen whose diameter is about one-third that of the mamelon. The neck of the mamelon is straight in most specimens and grades downward into the gently concave surface of the boss; in a few specimens the neck is slightly undercut in which cases a narrow flush platform is developed; basal terrace faint and but little elevated; the scrobicule is narrow, its width being about one-fourth of the radius of the intrascrobicular area, its floor is sunken but a trifle below the extrascrobicular surface; a well defined scrobicular circle marks the limiting boundary of the intrascrobicular area.

The extrascrobicular area, as here interpreted, is that part of the surface between the scrobicular circle and the sutures, which surface in our specimens is polygonal or subpolygonal in outline. The scrobicular ring is imperfectly developed on most plates and consists of a few low, irregularly spaced, rounded nonscrobiculate tubercles; the presence of a perforation is

58 Revision of the genera and great groups of the Echinoidea. Jour. Linn. Soc., Zool., xxiii, pp. 295-304; 1889.

doubtful; beyond and among these on the intertubercular tracts of some plates a few scattered granules are present. The total number of tubercles and granules is fifteen, or perhaps less, to twenty. The sutures vary in number and development according to the position of the plate in its column and of the column in the interambulacrum; the two most prominent and constant sutures are the two adoral oblique or "orad-interradial" sutures of Bather,[59] these two in a few specimens meet adorally at various angles but usually at about 90°, see figure 42, plate XLVIII; however, the angle thus formed is normally truncated by a transverse adoral suture; the adapical oblique or "apicad-interradial" sutures meet adapically in a very few instances, see third specimen, figure 36, plate XLVIII; in some specimens the last named sutures are truncated by a transverse, fairly well defined adapical suture, see fourth specimen, figure 36, plate XLVIII, thus making the elevated parts of a few plates hexagonal, but these are comparatively rare; the most common adapical condition of the sutures is one in which the apicad-interradial sutures meet in a curved line, the curved part supplanting the transverse adapical suture, see figure 40, plate XLVIII.

FIG. 76.—Meridional section of an interambulacral plate of *Nortonechinus welleri*, about x5. The left hand end of the drawing is adoral. The adoral transverse suture is more abrupt in most plates than in the figure. Drawn by O. T. Walter from specimen U. I. C. 3096, the right half of which was ground off perpendicular to the surface of the plate.

The marginal border extends outward on all sides from the bounding sutures, its greatest extent being adoral, while a narrow flange extends completely around the plate; the edges of the plate proper, at the suture lines, are nearly vertical, in a few cases even a little undercut along the orad-interradial and adoral sutures, while adapically the edge is concave and grades gently into the flange. The adoral margin of the flange is lobate and subparallel to the adoral suture when that is present; in many specimens the adoral portion flares laterally, in which cases its width is greater than any other transverse dimension of the plate; the bevelled surface of the adoral flange is variously grooved and excavated, into the hollows of which fitted

59 Bather, F. A., Triassic Echinoderms of Bakony: Resultate der Wissen. Erforsch. des Balatonsees; vol. I, part 1, p. 61; 1909, Budapest.

similarly shaped eminences found on the inner bevel of the overlapping plates; there is no regular pattern on the bevelled surfaces and yet in a general way the right and left thirds of the inner bevels are excavated more than their centers and the adoral margin of the outer bevel in many plates is set off as a thin border from the rest of the imbrication; see second specimen, figure 1, plate XLIX; the adapical part of the flange is thin and is often produced medially as in figure 40, plate XLVIII.

The measurements of four typical plates in millimeters are:

	a	*b*	*c*	*d*
Height, or meridional diameter (greatest)	7.7	7.9	7.5	7.6
Width, or greatest transverse diameter	7.2	7.4	7.5	7.2
Height within the sutures	4.7	5.0	4.4	5.1
Width within the sutures	5.2	5.6	5.4	5.5
Diameter of the scrobicular area	3.1	3.4	3.5	3.4
Diameter of the boss	2.4	2.5	2.5	2.8
Diameter of the mamelon	1.5	1.6	1.7	1.55
Diameter of the foramen	.7	.75	.6	.7
Greatest thickness	2.8	2.5	2.45	2.4

A study of a group of plates assembled at random shows that the amount of imbrication is large, that the irregularities and eminences on the outer bevels had their counterparts on the opposing inner bevels, that when the proper plates were in juxtaposition the narrow adapical imbricating margins fitted more or less well against or beneath the nearly vertical or slightly undercut adoral transverse sutures; moreover, assuming that the interambulacrum had three or more columns of plates, it is seen that each plate (except the adradials) lapped adapically upon the extended margins of three plates and was in turn lapped adorally by three other plates.[60]

The structure of the plates under a lens shows the open cribriform tissue or stereom characteristic of the skeletal parts of echinoderms.

Ambulacral plates imperfectly known. On the inner surface of the type specimen, see figure 2, plate XLVII, is a row of sixteen small plates more or less firmly cemented and standing partly on edge. Their position among the debris is such that they cannot be wholly uncovered or readily removed. The series lies in a sigmoid curve and the plates are apparently in

60 This paragraph was written before the type specimen, number 3044, was found.

serial order, judging from the perfect way in which they fit together. An end plate of the row is so inclined as to expose its inner surface. It has a pore-pair whose openings pass obliquely through the plate. The openings are close to one millimeter apart and are approximately in line with the transverse diameter of the plate, which dimension is 4.8 millimeters. Thickness of the plate is one-half millimeter. Toward one end the plate narrows perceptibly; from one side of the wider end and opposite the pore rises a thickened process which curves outward and away from the body of the plate in a sort of hook; this fits over a similar process on the next plate and so on throughout the series. Total thickness of plate including the process is two millimeters. These overlapping hooks apparently have to do with a well developed adoral imbrication.

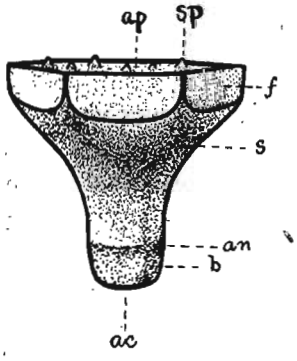


FIG. 77.—Diagram of a primary spine of *Nortonechinus welleri* Thomas to illustrate the terminology used in the text. *ap.* apex, *sp.* spinule, *f.* facet, *s.* shaft, *an.* annulus, *b.* base, *ac.* acetabulum. Fine microscopic striae pass longitudinally over the shaft and facets and converge to the center of the apex. Drawing by *E. Drewelowe Van Ek.*

The spines are short and expanded distally to such an extent that over the greater part of the test they seem to have been so crowded as to truncate each other by mutual compression. The condyle or acetabulum is round and broad, its depth about one-half its diameter, its margin sharply marked by a ring above which rises the base of the spine; the base has a gently convex surface and ends distally in a well defined annulus; the shaft contracts a small but perceptible amount above the annulus then its sides diverge gently at first thence abruptly to the broad terminal expansion; in a few specimens the shaft is subcylindrical for approximately half of its length above the annulus. Viewed apically most spines are polygonal in outline while only a few are rounded polygonal or circular; the number of sides most commonly observed is six, but specimens with five or even four sides are not rare; the sides are of slightly different lengths so that approximately perfect hexagons, pentagons, or squares are infrequent, especially the last. Another

common outline is the subpolygonal in which some of the sides meet forming marginal angles while the remainder of the periphery is rounded. The apical surface is flat or nearly so and its greatest transverse dimension is often equal to or greater than the length of the spine; the surface is normally at right angles to the shaft but in a few specimens it is a little oblique; the sides of the polygonal apical portion when truncation is well developed form flat oblong facets whose surfaces are subparallel to the axis of the shaft and each is bounded by three straight and one curved line. (See text figure 77.)

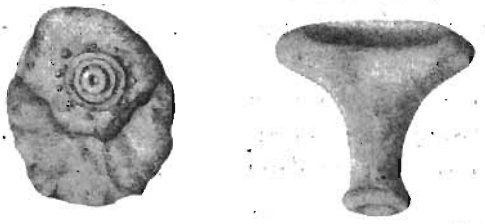


FIG. 78.—Interambulacral plate and primary spine of *Nortonechinus welleri* Thomas. Enlarged three diameters. Spine tilted to show the condyle or acetabulum. See figure 3, plate XLIX. Drawings by Miss Hilda Horn. In the drawing the scrobicular ring of tubercles occupies too small a part of the extrascrobicular area; compare the original.

The surface of each spine above the annulus is marked by exceedingly fine longitudinal striations, twenty-five to thirty in one millimeter; the striations continue up over the facets and the flat summit area where they converge from all sides toward the center. The summit is further ornamented by numerous short, blunt spinules or pustules which have a more or less definite radial arrangement; these spinules interrupt the courses of the striations and cause them to take winding paths quite in contrast with the precisely parallel courses pursued on the shaft.

A study of a number of spines whose apical expansion is round in outline brings out the facts that these spines are somewhat more slender, their summits tend to be shallowly concave instead of flat, their spinules are best developed marginally with a tendency to have a single prominent central spinule; in one specimen at hand the expanded apex is crateriform with a nearly smooth rim and in another the distal end is narrowly spatulate with a low longitudinal ridge along the center of one face of the spatula. A few spines, fully twice as long as those with the polygonal distal expansions, are nearly cylindrical for their entire length and terminate in three to seven sharp and fairly long subparallel points or prongs.

Measurements of four typical spines with six-sided apices are:

	a	*b*	*c*	*d*
Length (all figures in millimeters)	6.1	6.5	6.2	6.3
Greatest diagonal width across the apex	7.0	7.1	6.2	5.1
Greatest width of apex perpendicular to one of its sides	6.1	6.4	5.3	4.5
Vertical width of a facet	1.3	1.2	1.1	1.2
Diameter of the annulus	2.1	2.2	2.0	1.9
Height of the base	.7	.9	.9	.8
Diameter of acetabulum	1.4	1.6	1.5	1.4

Four of the long spines, Nos. 3051*a, b, c, d,* (Pl. XLIX, figs. 18-21) give a length and average diameter of shaft, respectively, as follows: 13.5, 2.5; 12.2, 2.6; 12.1, 2.5; 10.9, 1.9 mm. Specimen *b* is incomplete.

The lantern is represented by a few incomplete teeth, a part of a pyramid, and several finely preserved rotulas or braces. These have been found in close association with spines and plates.

Tooth gently curved longitudinally, inner surface flat with a shallow median groove which widens distally in most specimens at hand. The face of the tooth has a deep median groove flanked on each side by a rounded ridge; the slope from each ridge to the sharp-edged margins is broken by another but shallower groove which parallels the edge of the tooth; thus there are on the face three grooves, one median and two submarginal. The point is bevelled off from the face side and is strengthened by two sharp converging ridges which are continuations of those on the face. Under a lens fine lines are seen to run diagonally from the median groove to the edge of the tooth; these give each surface a herring-bone pattern. Total length of a tooth unknown. Specimen 3046a is 7.4 mm. long, 3.1 mm. wide, and 1.0 mm. thick; length of the bevelled point is about equal to the width of the tooth. Specimens of teeth are lighter in color than other parts and they break readily along the calcite cleavage.

Rotula strong, quadrangular in shape, wider than thick; both ends notched, the inner end deeply, the outer shallowly and broadly; a curved ridge borders the edge of the inner notch on the upper surface, beyond which the surface is flattened or depressed. The under surface bears a long V-shaped elevated

area, the point of the V being near the inner end and separated from the notch by a shallow transverse groove. Dimensions in millimeters of three rotulas follow:

No.	length	width at midlength	thickness at midlength
3047	8.2	3.2	2.0
3048a	8.6	3.7	1.9
3048b	7.5	3.4	1.9

On the inner side of the type specimen is an example 11.5 mm. long; it is the longest rotula seen but its width and thickness are about average. Near it lies what seems to be a compass with only one end exposed. On the same surface and firmly attached in the matrix is a half pyramid, face view, showing deep pit for the retractor muscle; the specimen is close to 12 millimeters long.

The high specialization of this echinoid is extraordinary. The remarkable development of the imbrication must have afforded great flexibility to the test but it would seem that the flexibility was somewhat limited by the crowded spines. The cover of spine apices formed a more or less complete coat of mail over the test and its function could have been little other than that of protection. So completely did it envelop the test that the development of secondary spines is doubtful; the miliaries are very short—however, on parts of the test where the primary spines were not crowded they may have been longer. The long spines with the rounded or forked terminations differ from those of *Xenocidaris* in not being fluted, their shafts are stouter, and the marginal spinules are less regular.

A study of the primary spines throws little light on their orientation but by analogy it may be inferred that the greatest diagonal dimension of a six-sided apex is parallel to the equator of the test as is the case with hexagonal plates of the columns. The variations in the shapes and sizes of the spines, as pointed out by Bather[61] in his study of the radioles of *Anaulocidaris* and other genera, are not merely between spines of the same rank but there is a definite gradation of form according to the position of the spine on the test. The age of the spine is also a factor in variation while the degree of crowding undergone by the various spines determines quite largely the shape of the distal expansion as well as the sharpness of its marginal angles. In a communication some years ago Doctor Bather kindly suggested to the author that the spines of *Nortonechinus* are similar to the radioles of *Anaulocidaris* and that by analogy the roundly terminated spines of the former belong on the less crowded apical part of the test as in the latter. The very long prong-bearing spines are assumed to have been circumapical in position. However, their subsequent modification to short ambital spines demands progressive changes of which we do not have at present sufficient and convincing intergrading forms.

The nature of the type specimen permits some speculation on the size and shape of an entire individual. Transversely the specimen measures fully six centimeters; since apparently neither of the lateral columns is an adradial we must assume that there were at least two more columns in the interambulacrum, add to this the width of an ambulacrum and the width of the two areas would be at least eight centimeters. Multiplied by five this would give a circumference of forty centimeters or a diameter of close to 12.75cm.; add to this the length of the spines (6.3mm. x 2) and we would have a diameter of over fourteen centimeters or five and one-half inches for the living animal. Thus, if spherical in shape, it would approach the size of a large *Melonechinus*

61 loc. cit., pp. 136, 137.

like those of the St. Louis limestone. The few long spines with the spiny terminations recall the flattened radioles about the basal rim of the hemispherical test of *Colobocentrotus* and like them may have been used as aids in locomotion. In such an event *Nortonechinus* may have been more or less hemispherical in shape; indeed it is difficult to understand how a form so encumbered by its type of primary spines could have moved about unless it had something of the shape of the Hawaiian *Colobocentrotus*. More complete tests are awaited with interest.

The shape of the teeth is very different from those of the Mississippian echinoids in that they are not keeled but are nearly flat. No known Mississippian echinoid seems to have inherited the features of *Nortonechinus*, which evidently reached its climax in the late Devonian and left no descendants.

The type specimen is in the University of Iowa collection; typical plates and spines have been sent to Doctor Jackson and are in the Museum of Comparative Zoology at Harvard; there is also a lot in the Walker Museum, University of Chicago, in the British Museum, London, and in the United States National Museum, Washington.

Occurrence.—Found in the marly shales of the Lime Creek beds in a zone ten to fifteen feet above the plastic blue shales. Locally they are abundant but at several stations at which this horizon is well exposed very few specimens have been found. The hillsides about the Rockford Brick and Tile Plant have proved good collecting places; Juniper Hill or "Nortonechinus Hill" about a mile to the northwest of the Tile Plant has yielded hundreds of spines and plates from small patches a yard or two in width. Dr. Norton's original collection of about twenty plates and some thirty primary spines was collected "on a small spot at Hackberry Grove."

The specific name is given in honor of Dr. Stuart Weller of the University of Chicago, under whose direction this study was initiated.

NORTONECHINUS WELLERI VAR. LATUS n. var.

Plate XLIX, figs. 24-33.

At one locality in Cerro Gordo county, about one-half mile to the northwest of Bird Hill, Mr. C. H. Belanski found a considerable number of plates and spines which differ in some ways from the typical plates and spines assigned to *N. welleri*. The plates are relatively thinner and larger and the spines are more robust than in the latter species.

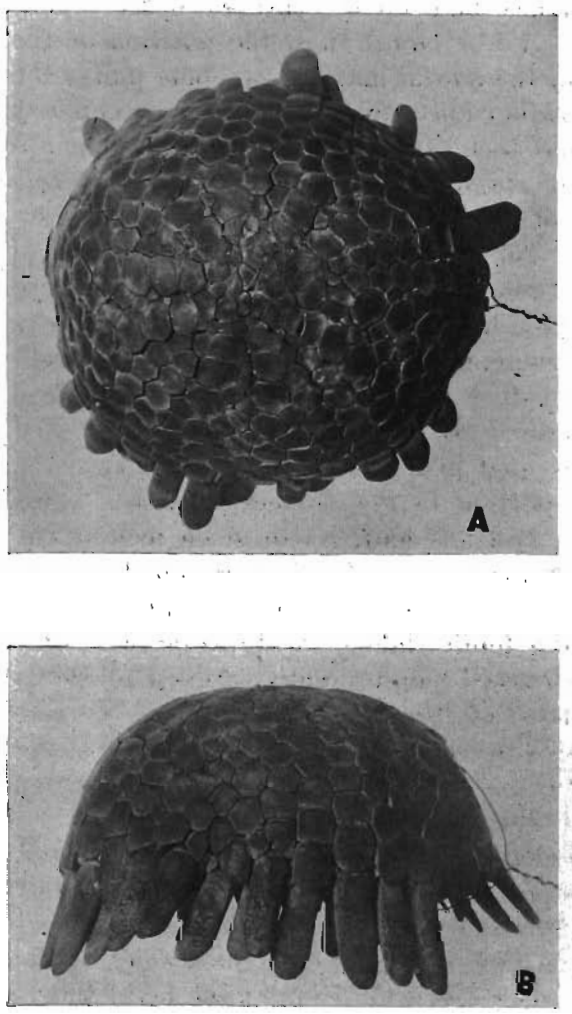


FIG. 79.—*Colobocentrotus atratus* Brandt. Apical (A) and lateral (B) views, natural size. The spines of this modern species, as in the Devonian *Nortonechinus*, are expanded distally until their polygonal surfaces form a coat of mail over the greater part of the test. The broad flattened spines of the ambital region are not like any in the test of Nortonechinus.
Pacific Ocean; Necker Island, Hawaii. Zoology Museum; C. C. Nutting, collector. (U.I.C. 18877.)

Later on the writer visited the place with Mr. Belanski and a large additional lot was obtained. No plates intermediate in size were collected, all being broader and more rounded than those of the type species. The spines are typical but are relatively larger.

NORTONECHINUS OWENENSIS n. s.

Plate L, figs. 26-35.

Species based on a large number of interambulacral plates, a lot of incomplete spines, and some parts of the lantern. They occur in a weathered marly zone in which they have been rather poorly preserved. On account of their imperfection the diagnostic characters are somewhat obscure, hence they are referred to this genus with some hesitancy.

Interambulacral plates irregular in shape, proportions of width and length variable, edges very thin; main tubercle fairly large, out of the center on most plates, perforate, faintly

scrobiculate, basal terrace and other features obscure, but thought to be present. A few plates show the position of the sutures and the bevel of the adoral margin; on some plates the margin of the bevel is rather abruptly bent inward. Secondary tubercles very small and seen only on a few plates, being apparently worn away or absent on most plates. Ambulacrals unknown. Fragments of eleven spines have been found associated with the plates. They are all slender-shafted and small when compared with those of *N. welleri.* Moreover, those which preserve the apex terminate in a trident of slightly divergent spinules. Acetabulum broad, limited by a well-marked ring; base spreading to a definite annulus. Surface marked by fine longitudinal striations.

The lantern is represented by parts of three hemipyramids. They are small in proportion to the associated plates. One specimen, number 3063, is a left half, its foramen magnum is wide-angled and it has a prominent lateral wing—on the interpyramidal surface of which oblique ridges may be faintly seen; on the inner surface the tooth slide is well preserved. The outer face is noticeably curved longitudinally; a deep retractor muscle scar traverses most of the face. Dorsally are two pits of considerable size which presumably mark the position of the epiphysis. Total length, 5.5 millimeters, thickness from outer face to point of lateral wing, 3.1 millimeters.

The rather indefinite shape and featureless character of most of the plates of this species as well as the excentric position of the main tubercle do not conform closely to the regular and clear-cut outlines and marking of plates of other species of the genus. Some features, such as the position of the main tubercle, the irregular shape, and the faintly shown or absent secondaries, remind us of *Lepidocentrus* of the type of *L. eifelianus.* (See Phylogeny of the Echini, Plate 20, figure 14.) The presence of sutures and bevelled marginal borders of the *N. welleri* type on a few of the best preserved plates, however, makes reference to *Nortonechinus* more plausible.

Wherever loose plates of *N. welleri* or of *N. welleri latus* are collected, about an equal number of the large primary spines with polygonal apices are obtained. At the type locality for

N. owenensis over seventy plates were obtained and not a spine of any other type than those described above and but a few of them. Their small size and broken condition, however, make them less conspicuous than the plates and hence harder to find. Further collecting may disclose the larger spines but it is extremely unlikely.

Position and locality.—Owen substage, Lime Creek beds; in gutters along roadside between section 36, Mason township, and section 31, Portland township. The type locality is about seventy-five yards north of the wagon bridge over Owen creek near the home of Mr. Timothy E. Wagner. They occur in a weathered marly shale just beneath the thin overlying drift at a horizon about thirty-five feet above the *Idiostroma* ledge which marks the base of the Owen beds. The type locality is in Cerro Gordo county.

NORTONECHINUS STAINBROOKI n. s.

Plate XLIX, figs. 34-43; text fig. 80.

FIG. 80.—Interambulacral plate of *Nortonechinus stainbrooki* Thomas, about x3. Collected at exposure number three, Independence shale, south of Brandon, Iowa. (U. I.C.3101.)

Known only from a few primary spines and one interambulacral plate found in the Independence shales.

The interambulacral plate is of medium size, nearly uniform thickness, and strong aboral imbrication. It is rounded polygonal in outline, longer than wide, its greatest width being just adapical to the main tubercle. The marginal border is quite narrow adapically but is well developed adorally. On the adoral bevel the lateral or adradial tracts are much larger than the median tract, indicating that the imbricating plate next adoral in the column did not have large areal contact with it. The positions of the sutures are obscure except the two adoral oblique (orad-interradial) and these two are low and meet in an angle which tends to obliterate the transverse adoral suture. The adapical transverse and apicad-interradial sutures are not defined; this part of the plate is rounded and its extrascrobicular surface merges into the marginal border. The mamelon is smoothly rounded, perforate, neck straight, flush platform

narrow. Basal terrace and scrobicular circle indefinite due to wear but there is a well marked scrobicule. Secondary tubercles low, scattered, practically aborted between the adoral oblique sutures and the scrobicular circle where the extra-scrobicular area is quite narrow—adorally one or two tubercles occupy the angle.

Dimensions.—Length 9.0 mm., width 8.1 mm.

The primary spines are notably short and stout. Each spine expands abruptly from the annulus to the very broad and thick apex. The base is short and there is little or no contraction above the annulus. Apices of all the specimens are sharply polygonal. Surface markings much as in *N. welleri.*

Among the hundreds of primary spines of *N. welleri* collected in Floyd and Cerro Gordo counties in the Lime Creek beds it would be difficult to select a single specimen approximating the short shafts, abrupt expansions, and relatively broad terminations of the spines of this lot from Benton county. The measurements in millimeters of five typical specimens follow:

	a	*b*	*c*	*d*	*e*
Length	4.2	5.1	5.0	4.7	6.0
Greatest width of apex	8.5	9.0	8.5	7.5	8.2

Occurrence.—Independence shale, outcrop number three, near Brandon, Iowa. Twelve spines and one plate. Here they occur with *Arthracantha mamelonifera, Douvillina variabilis, Dalmanella infera,* and other typical Independence fossils. Collected by M. A. Stainbrook.

Xenocidaris Schultze.

Genus based by Schultze upon a number of trumpet-, club-, or bell-shaped spines found in the German Devonian unassociated with any other part of the test.

The Iowa material consists of scores of spines, a half pyramid, and a single interambulacral plate with a strong central tubercle and a wide adoral bevel. Spines slender-shafted with well defined acetabulum and annulus; apical expansions variously modified as in *X. clavigera* Schultze.

The writer doubts that the spines described as *X. cylindrica* Schultze really belong to this genus since they are spindle-

shaped, covered with nodose spinules, and bear a milled ring; moreover they are much longer than the spines of the other *Xenocidaris* species, one specimen reaching a length of 55 mm.

Middle Devonian of Germany; Upper Devonian of Iowa.

XENOCIDARIS AMERICANA n. s.

Plate L, figs. 1-25.

Compare *Xenocidaris clavigera* Schultze, Monograph der Echinodermen des Eifler Kalkes, p. 14, pl. xiii, figs. 3, 3a-h, 1866; also Jackson, Phylogeny of the Echini, with a Revision of Paleozoic Species, Mem. Boston Soc. Nat. Hist., vol. 7, p. 455, text fig. 256a-d, 1912.

Interambulacral plate is irregularly polygonal but wear and breakage prevent our knowing its exact original shape. It has a prominent tubercle with a broad foramen and there is some evidence of a basal terrace and a scrobicule. The adoral bevel is wide and hollowed out transversely just below the adoral suture; the edges of the plate are thin and fragile. Greatest length, 5.8 mm., greatest width, 5.0 mm.

Spines trumpet-shaped or club-shaped, with very slender shafts especially just above the annulus, round in cross section, tapering gradually upward—the taper beginning just above the annulus in some specimens but confined to the distal half or even less in others. Each spine terminates in a more or less flat or slightly concave surface surrounded by a subcircular marginal coronet of blunt spinules which are somewhat irregularly spaced and vary from five to twelve in number; viewed from the side the spinules in many cases are seen to be continuations of ridges on the fluted surface of the expanded part of the spine. The terminal face of most specimens is at right angles to the axis of the spine but in a few it is slightly oblique; from the center of the terminal face rises a blunt rounded spinule seldom higher than the spinules of the coronet and similar to them; on a few specimens the single spinule is replaced by a central cluster of two to six spinules. Acetabulum shallowly and broadly hollowed out, suggesting a large tubercle on the corresponding plate, deeply perforated centrally, its margin bounded by a definite ring; there is a well marked

annulus but no evidence of milling. The surface of the spines above the annulus is marked by exceedingly fine longitudinal striae which apparently do not continue over the apical surface, their place being taken by very fine granulations. In a little more than two hundred spines in the collection at hand only three or four specimens show any sign of compression of the apical termination as is the case with most of the spines of *Nortonechinus*. One of these is compressed on four sides into a polygon, the others are flattened on one or two sides only. The only noticeable modification as a result of the compression is the partial suppression or elimination of the marginal spinules and a tendency to develop irregularly distributed apical pustules.

Dimensions of a complete spine, number 3074, are: length, 11.5 mm.; diameter of apex, least, 3.9 mm., greatest, 4.2 mm.; diameter of base, 1.9 mm.; diameter of shaft at midlength, 1.6 mm.; height of base, 1.0 mm. Several incomplete spines indicate sizes larger than those attained by this one while many are considerably smaller.

The jaw apparatus is represented by a nearly complete left hemipyramid of interesting proportions. It is twelve millimeters in length and much less curved than those of *Devonocidaris* described on a subsequent page. On the inner face the dental slide extends about two-thirds the length of the specimen; distal part above the pyramidal suture broken away, foramen magnum evidently quite shallow; corrugations for interpyramidal muscles are very fine but can be seen over the entire surface with a hand lens. They cross the area transversely, being arched distally toward their midlength. The outer face is traversed longitudinally by a deep retractor muscle scar which extends nearly the whole length of the specimen.

The spines of this species resemble superficially some of the rounded spines of *Nortonechinus welleri*. However, the spines of *X. americana* are more slender, have a marginal coronet, are fluted in most cases, and the hollowed-out apical surfaces are not marked by fine striations. Compressed polygonal terminations are the rule in spines of *N. welleri*, the reverse condition

prevails in *X. americana*. A mixed lot from the two species can be separated with ease. The poorly preserved interambulacral plate suggests a high degree of imbrication; this together with other less satisfactory characters suggest probable family relationship and both are placed in the Archeocidaridae.

Position and localities.—At the base of the marly fossiliferous shale at and just above the contact with the blue plastic shale of the Lime Creek beds. At this zone, here designated the *Xenocidaris* zone, the shale is in many places somewhat pyritic and the spines and other parts are darker in color than the fossils of beds ten feet higher. In collecting *Xenocidaris* parts it has always been kept in mind that spines and plates of *N. welleri* might be among them due to wash or slump from above. None have so far been encountered and in fact at the spots where *X. americana* have been found it happens that no finds of *N. welleri* have been made in beds exposed on the slope immediately above them. The best finds of *X. americana* have been obtained by digging out the black shale where they occur and then working it over with supplementary washing and screening. Most of the specimens for this study were obtained near the east end of the pit of the Rockford Brick and Tile Company. The places have now been worked out for clay.

LEPIDOCENTRIDAE Loven

Test spheroidal or flattened horizontally, circular in the ambital plane, pentagonal or elongate through the axis III, 5. Two columns of plates in an ambulacral area. Pore-pairs uniserial or slightly biserial. Ambulacral plates imbricating adorally and beveled strongly under the adradials. Interambulacra with numerous, five to fourteen, columns of plates in an area, moderately thin to very thin. Interambulacral plates imbricate strongly aborally and from the center outward and over the ambulacrals. Oculars are small, insert; genitals wide, low, with many pores as far as known. Lantern inclined, composed of forty pieces. (Modified after Jackson, Phylogeny of the Echini, page 284.)

DEVONOCIDARIS Thomas

1920. *Devonocidaris* Thomas. Bull. Geol. Soc. Amer., vol. 31, p. 212.

Genus known only from isolated plates, spines, and parts of the lantern found massed together in a thin bed in the marly fossiliferous zone of the Lime Creek shale.

Interambulacral plates small, very thin in proportion to area, polygonal or possibly rhombic in outline; complete plates are rare, the most perfect ones, however, are essentially five- or six-sided with little or no evidence of imbrication. Each plate bears a prominent central or subcentral tubercle, perforate, noncrenelate, and the boss is bordered by a basal terrace; no scrobicular ring of tubercles but a few scattered secondaries are present on the extrascrobicular areas of some plates. Ambulacral plates small, transversely elongate, with a terraced perforate tubercle at one end and a pair of pores near the other and narrower end. A few of these plates show evidence of imbrication. Spines slender, acicular, vertically striated. Lantern inclined and wide-angled; each tooth with a median longitudinal groove on its convex surface and a nearly smooth flat concave surface.

From *Archeocidaris* M'Coy, of the Mississippian, *Devonocidaris* differs in the absence of a definite scrobicular ring, and in having long slender spines which fit nowhere into Jackson's key to the spines of that genus. (See Phylogeny of the Echini, p. 258.) The presence of a basal terrace precludes reference to *Eocidaris* Desor. The strikingly different spines and the strong imbrication in *Nortonechinus,* herein described, exclude it from that genus. In the writer's opinion, its affinities are with *Lepidocentrus* Müller; reference to the family Lepidocentridae, however, is made with some hesitation and until at least associated interambulacrals are found throwing light on the question of imbrication the family reference can not be satisfactorily settled.

DEVONOCIDARIS JACKSONI n. s.

Plates L, 36; LI, 1-26; LII. 1-4; LIII, 1-7; LIV, 1-6.

Species founded on abundant specimens of isolated interam-

bulacral and ambulacral plates, spines, and parts of the lantern confusedly intermingled in thin calcareous slabs on the surfaces of which the specimens are weathered out into more or less sharp relief. The parts are so delicate and fragile that any attempt to remove them from the slabs or to uncover hidden edges invites damage to the specimen; even most careful cleaning has in several cases proved disastrous. In spite of this difficulty an abundance of most of the parts has been found in excellent condition.

Interambulacral plates very thin, small, and delicate; outline polygonal, but in most cases incomplete due to the breaking away of parts of the thin edges; the general shape of the more perfect plates is hexagonal or pentagonal (adradially). No definite evidence of imbrication, hence orientation of plates is uncertain. Primary tubercles prominent, central or subcentral; mamelon round, centrally and rather deeply perforated by a round foramen, dome smooth, neck straight or slightly undercut in some specimens; flush platform narrow and without a parapet; from the platform the surface of the boss passes downward with an even or gently concave surface to a low but distinct basal terrace. Secondary tubercles irregularly distributed, one to four, rarely five, in number, some plates have none; a few of the larger secondaries are distinctly mamelonate and have a very low but obvious terrace. Tertiary tubercles showing perforations occur rarely. A few scattered granules complete the ornamentation. On a few plates (adradials) one edge is distinctly scalloped; the scallops, three or four in number, appear to be for the reception of the ends of the ambulacral plates along the adradial suture. Under side of the plates smooth. With good lens the cribriform tissue of the plates may be readily seen.

Ambulacral plates small, thin, delicate, transversely elongate in most cases and bearing a pair of subequal oval pores whose long axes converge; margins of the pores elevated into a distinct rim on most plates while on a few a well defined peripodium is present. The pore-pair lies toward the narrower end of the plate while the broader end bears subcentrally a prominent perforate tubercle which when well preserved is

surrounded by a low basal terrace similar to that of the secondary tubercles of the interambulacral plates; the pores pass through the plate obliquely downward and toward the tuberculate end—as a result the pore-pair is more nearly central on the inner surface. On the inner surface of some plates there is what appears to be slight bevelling suggesting adoral imbrication but the character is not constant. Smaller plates are found with transverse diameters of one-half or less that of the ordinary ambulacrals but they are not common; these bear a pore-pair identical with the others but smaller and nontuberculate; they are thought to be demiplates or primaries from the extremity of the ambulacrum.

Compound plates of small size, irregular shape, and delicate structure occur sparingly; they are variously perforated by four or six pores (one has five); the pores are smaller and more narrowly oval than those of the primary plates and are arranged in pairs in the form of an arc of varying degree of curvature on different plates. The apical system is represented in the collection by a subangular genital plate which bears the "madreporiform tubercle" or madreporite. The plate is pierced by two round genital pores which are about twice as far apart as either pore is from its edge of the plate measured transversely. The porous area is subcentrally located being confined to that part of the plate adapical to the two large pores but not reaching the adapical edge.

Dissociated parts of the lantern are relatively common. The lantern appears to have been strongly inclined and fairly wide-angled. No complete pyramids and only doubtfully complete hemipyramids have been seen. Foramen magnum moderately deep. Each maxilla bears a gently curved dental slide divided longitudinally into two nearly equal parts by a slender ridge which runs parallel to the symphysis, becoming more slender aborally and ending in a more or less free point—the styloid process—at a short distance below the margin of the foramen magnum. Corrugations for the attachment of the interpyramidal muscles pass inward and downward over the interpyramidal face; the peripheral face bears an elongate retractor muscle scar which is deep adorally but shallower and

less well marked dorsally. Dorsal surface of the maxilla apparently smooth but preservation obscures this point in many cases, in some of which the epiphyses may be present. Teeth of a distinctly lighter color than other parts of the lantern and very well preserved except for breakage along calcite cleavage planes. Tooth gently curved, its peripheral surface traversed by three longitudinal grooves as seen in cross section; the depth of the median groove is fully one-third the thickness of the tooth; the sides and floor of this groove are rounded but in some cases almost V-shaped in section; the lateral grooves are situated one on each slope midway between the center and the thin lateral edges, they are quite shallow and appear to be counterparts of the ridges in the floor of the dental slide mentioned above; on some teeth the outer edges of the lateral grooves are so prominent that they simulate slender ridges. The inner surface of the tooth is flat; under a lens it is longitudinally marked by exceedingly fine, shallow, parallel grooves separated by broad flat intergroove areas. Dorsal end of tooth more or less forked except when broken by cleavage; tip of tooth sharply cuneate, re-enforced on the back by converging extensions of the ridges on either side of the median groove and flanked by one or two sharp denticles on each side.

Rotulas slender, upper surface rounded, under surface toward the inner end bearing a more or less well defined median ridge. Both ends notched, the inner end the deeper, the outer end the wider; as viewed from the side some of the rotulas are somewhat curved.

Spines notably slender, straight, circular in cross section, and very fragile; base short, enlarging very gradually to the rather indefinite annulus, thence a trifle more slender for a short distance above the annulus and thence gradually expanding up to the normal size. Acetabulum round and shallow. Tip of the spine uncertain, a few show a bluntly rounded apex while others taper gently to a sharp termination. Practically all spines are incomplete, but in spite of this two or three sizes are apparent corresponding to the various tubercles described above and in addition a few minute miliary spines are attached to some of the plates. Very fine longitudinal striations mark

the total length of the spines, passing more or less obscurely over the annulus and base; there are twenty-five to thirty-five striations on each spine.

The following measurements taken in millimeters indicate the size and proportions of some representative parts:

Interambulacrals:	*a* on slab 3035	*b* slab 3011	*c* slab 3005	*d* slab 3012
Longest meridional diameter	2.9	2.5	3.7	3.6
Meridional diameter through primary tubercle	2.7	—	3.5	3.5
Longest transverse diameter	3.4	4.4	3.2	4.1
Diameter basal terrace	1.1	1.2	1.1	1.25
Diameter of mamelon	0.4	—	0.32	0.5
Diameter of foramen	0.15	—	0.12	0.2

Note: Interambulacrals *a*, *c*, and *d* are apparently adradials; *b* is a hexagonal plate. Each specimen is marked by a double ink ring on the slab.

Ambulacrals:	*a* slab 3013	*b* slab 3013	*c* slab 3013
Meridional diameter through tubercle	1.5	1.6	1.5
Meridional diameter between pores	1.1	1.1	1.2
Greatest transverse diameter	3.0	3.1	2.6
Distance from center to center of pores	0.5	0.6	0.5
Length of pore	0.6	0.5	0.6
Diameter of basal terrace	0.8	0.9	0.8

Demiplates:	*a*	*b*
Meridional diameter between pores	0.7	0.6
Greatest transverse diameter	0.8	1.5
Distance from center to center of pores	0.5	0.4
Length of pore	0.3	0.2

Note: Both plates are on slab 3001; *a* is in a double ink ring and *b* is near the edge.

Compound ambulacrals: Two diameters taken at right angles to each other on specimen *a*, slab 3010, are 2.4 and 4.5 mm.; specimen *b*, slab 3001, near the catalog number, has similar diameters of 0.4 and 1.4 mm.

Madreporic genital plate, on slab 3001.

Meridional diameter between the pores	1.2
Greatest transverse diameter	1.5
Distance from center to center of pores	0.8
Madreporic area	0.5 x 0.7

Sieve-pores about 14 in space of one millimeter.

Maxillae:	*a* slab 3001	*b* slab 3024	*c* slab 3004	*d* vial 3024
Greatest height	3.7	3.0	3.0	5.5
Greatest width	2.4	1.7	2.0	2.4
Length of œsophageal margin	2.4	1.7	2.0	3.2
Length of symphysis		1.9		
Width of dental slide		0.6		0.9
Corrugations	6 in. 1mm.	6.3 in 1mm.		

Teeth (specimens incomplete):	*a* slab 3020	*b* slab 3029	*c* slab 3013	*d* slab 3001
Length	4.7	3.5	3.0	3.0+
Width	1.9	1.0	0.9	1.03
Length of the tip	1.0	0.6		0.7

Braces: specimen *a*, slab 3031, near edge, length 4.1; width 1.3.
specimen *b*, vial 3925, longest one, length 4.0; width 1.0.
specimen *c*, slab 3001, near edge, length 2.3; width 0.6.
specimen *d*, slab 3016, length 2.6; width 0.7.

Spines (incomplete);	length	diameter	diameter of annulus
a, slab 3003,	11.4	0.3	0.5
b, slab 3032,	9.4	0.4	
c, slab 3003,	5.1	0.2	0.3
d, slab 3003,	7.2	0.3	0.35
e, slab 3003,	10.6	0.2	0.3
f, slab 3008,	2.8	0.02	0.022

The species is named in honor of Dr. Robert Tracy Jackson whose classic monograph on the "Phylogeny of the Echini, with a Revision of Paleozoic Species" has proved very valuable in the present study.

Position and localities.—Near the middle of the marly fossiliferous zone of the Lime Creek shale. The best specimens were obtained in gutters along the roadside about half way up Bird Hill, west edge of section 19, township 95 north, range 18 west. Also in the *Devonocidaris* horizon on the hills to the west and northwest of Rockford.

Explanation of Plates.

The illustrations on the following plates are all natural size unless otherwise indicated. The catalog number of all specimens in the University of Iowa collection is given in parentheses following the letters U. I. C. The location of other specimens illustrated is given in so far as it is known.

PLATE XXXV.

Figs. 1-11, 13, 18. *Strobilocystites calvini* White.

1. Oral view of the type specimen, natural size. 2. The same view x2. 3. Same specimen showing right rhomb and right anterior ambulacrum x1.5. 4. Same as figure 3 but turned slightly to the right, x2. Iowa City, S. Calvin. (U. I. C. 3503.)

5. Oral view of a nearly spherical example found near Iowa City. (Cornell College Museum.) 6. Thecal plate *14* found loose at Brandon. (U. I. C. 3509.) 7. Young individual. Iowa City, S. Calvin. (U. I. C. 3504.) 8. Imperfect calyx lacking the ambulacral plates but preserving the stem. Linder's Boathouse. (Fitzpatrick Collection.) 9. A badly crushed calyx with much branched ambulacra. Brandon, M. A. Stainbrook. (U. I. C. 3508.) 10. Stem x2, assumed to belong to this species. Brandon, A. O. Thomas. (U. I. C. 3510.) 11. Drawing of plate *23* showing hydropore and the double madreporite, after specimen 3502; about x5. This and figure 13 drawn by Mr. O. T. Walter. 13. Inner and outer cycles of plates forming the anal pyramid, about x6.7. One plate in the outer cycle missing. After specimen 3501; Sanders Quarry, T. J. Fitzpatrick. 18. Oral view of a large and somewhat damaged calyx showing madreporites and hydropore, about x1.5. Vinton, secured by W. S. Glock. (U. I. C. 3502.)

Figs. 12, 19-21. *Strobilocystites schucherti* Thomas.

12. View of left side showing pectinirhomb *12-18*, the sutures, and the relatively smooth plates, about x2. Nora Springs, C. H. Belanski. (U. I. C. 3505.)

19 Anal view of another example x2. Nora Springs, C. H. B. (U. I. C. 3506.) 20, 21. Left and oral views of a partly crushed specimen, about x1.5. Note the elevated ambulacra, the absence of branches, and the hydropore. Near Solon, L. P. Elliott. (U. I. C. 3507.)

Figs. 14-17. *Strobilocystites polleyi* Calvin.

14. Antanal view of the holotype showing pectinirhomb *1-5* and the sutures; about natural size. Drawing by Mr. Frank Bond.

15, 16, 17. Basal, anterior, and right ambulacral aspects of the holotype x2. Ambulacral plates are missing. Cedar county, J. F. Polley. (U. I. C. 3500.)

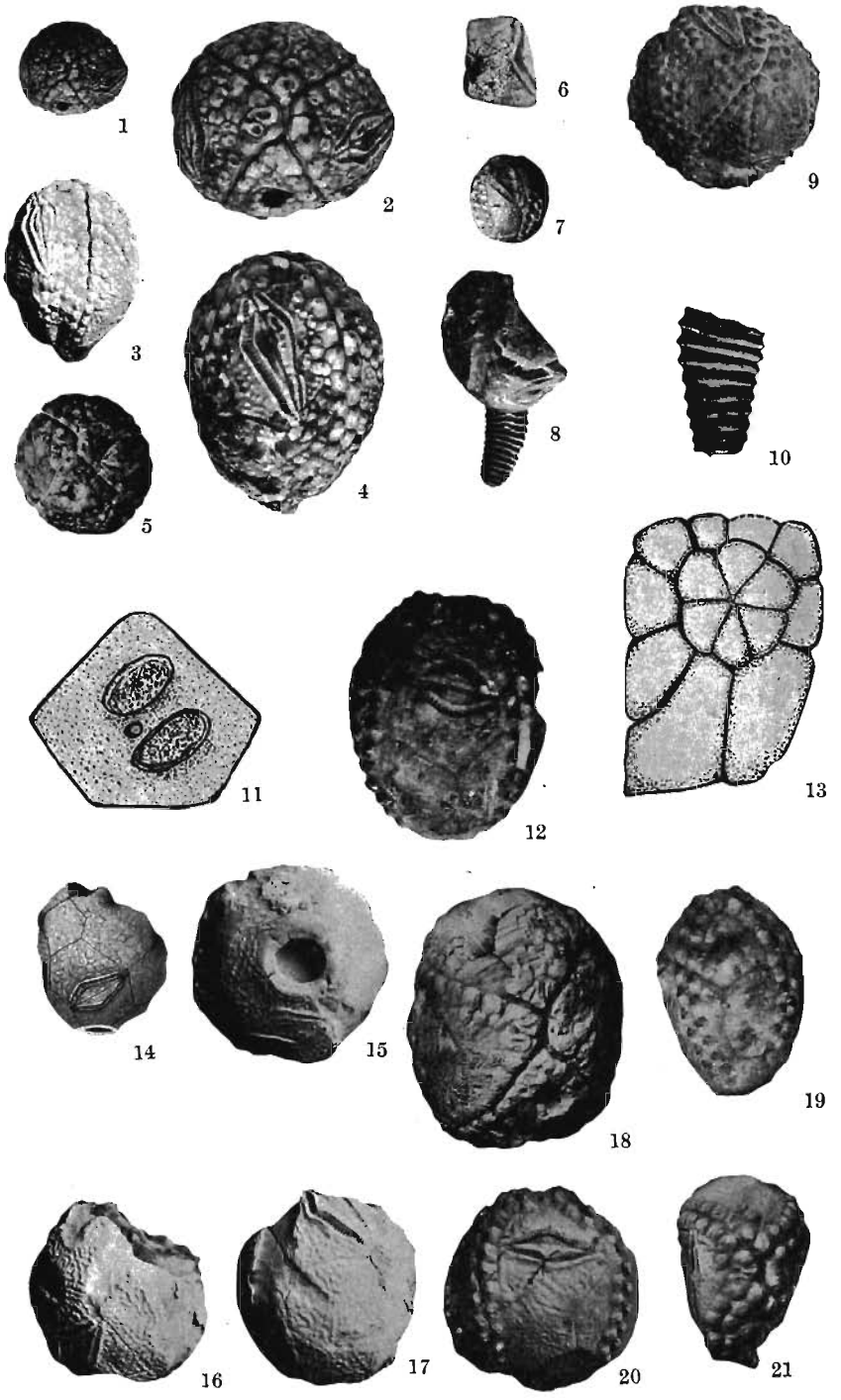

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PLATE XXXVI.

Figs. 1, 6-9, 16, 17. *Nucleocrinus obovatus* (Barris).

1. Left posterior view of an elongate calyx. One of Barris' types. Locality uncertain. (Museum Davenport Acad. Sci.)

6, 7. Anterior and basal views of a nearly perfect specimen, about x2. Sutures traced with ink. Iowa City, Frank Bond. (U. I. C. 3200.)

8, 16, 17. Left posterior side, about x2; posterior and oral views of a small, probably young, individual. Alpena, Michigan, W. H. Barris. (U. I. C. 3205.)

9. Left anterior aspect of a fine specimen. Alpena, W. H. B. (U. I. C. 3006.)

Figs. 2-5, 12, 18. *Nucleocrinus bondi* Thomas.

2, 3, 12. Left anterior, oral, and posterior views of a very perfect calyx. Linder's Boathouse, Anton Linder. (Fitzpatrick Coll.)

4, 5. Oral and left posterior views of the type, x2 and about x1.3 respectively. Near Iowa City, Frank Bond. (U. I. C. 3201.)

18. A stout but distorted calyx referred to this species. Rapid Creek, Carl Linder. (Fitzpatrick Coll.)

Figs. 10, 11. *Nucleocrinus meloniformis* (Barris).

10. Posterior view showing strongly elevated interambulacrum.

11. Left posterior ambulacral view of the same specimen x2. Waterfowl Bay, Michigan, W. H. Barris. (U. I. C. 3203.)

Figs. 13, 14. *Codaster gracilis* (Wachsmuth).

Lateral and oral views of two specimens introduced for comparison with the next. Alpena, Michigan, W. H. B. (U. I. C. 3208 a, b.)

Fig. 15. *Codaster subtruncatus* (Hall).

Lateral view, after Hall. Buffalo, Iowa.


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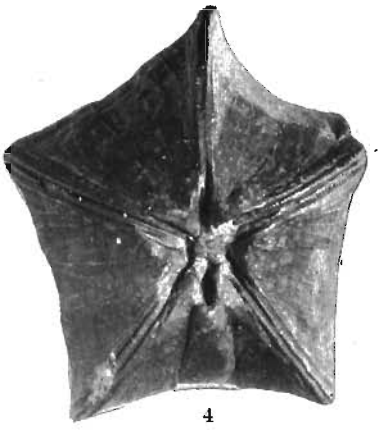
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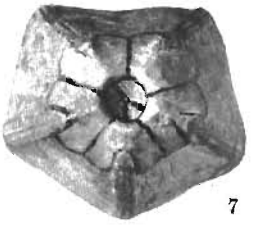
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PLATE XXXVII.

Fig. 1. *Melocrinus nodosus* Hall.

View of "right anterior ray." After Whitfield.

Figs. 2-4. *Melocrinus nodosus irregularis* Thomas.

2. Posterior aspect of the type showing plates of the anal interray. 3, 4. Basal and ventral views of the same. Brandon, M. A. Stainbrook. (U. I. C. 3600.)

Fig. 5. *Melocrinus tiffanyi* Wachsmuth and Springer.

Right posterior view of the type, after Wachsmuth and Springer.

Figs. 6-8. *Melocrinus calvini* Wachsmuth and Springer.

6. View of the left anterior ray. 7. Anterior aspect x1.4. 8. A figure after Wachsmuth and Springer. All are views of the holotype. Solon, S. Calvin. (U. I C. 3601.)

Figs. 9, 10. *Melocrinus (?) linderi* Thomas.

Two views showing the spinosity of the plates and the shape of the imperfect calyx of the holotype. On the right hand side of figure 10 the outline of the plates has been traced on the exfoliated and silicified surface. North of Iowa City, Mary Linder. (Fitzpatrick Coll.)

Figs. 11-16. *Melocrinus belanskii* Thomas.

11. Type specimen seen from the right side. 12. Basal view showing the abnormal radial cycle, about x2. Near Bird Hill, C. H. Belanski. (U. I. C. 3602.)

13. Radial plate x2, from the type locality. (U. I. C. 3751.) Figure inadvertently turned on its side by the engraver.

14. Figure showing the inner surface of a plate; slightly enlarged. Note the irregularly disposed nodes and ridges; these occur on all plates examined.

15, 16. Fragments of a stem attached to the clayey matrix, and view of a joint face. These occur abundantly with the loose plates and are assumed to belong to this species. (U. I. C. 3750 and 3752.)

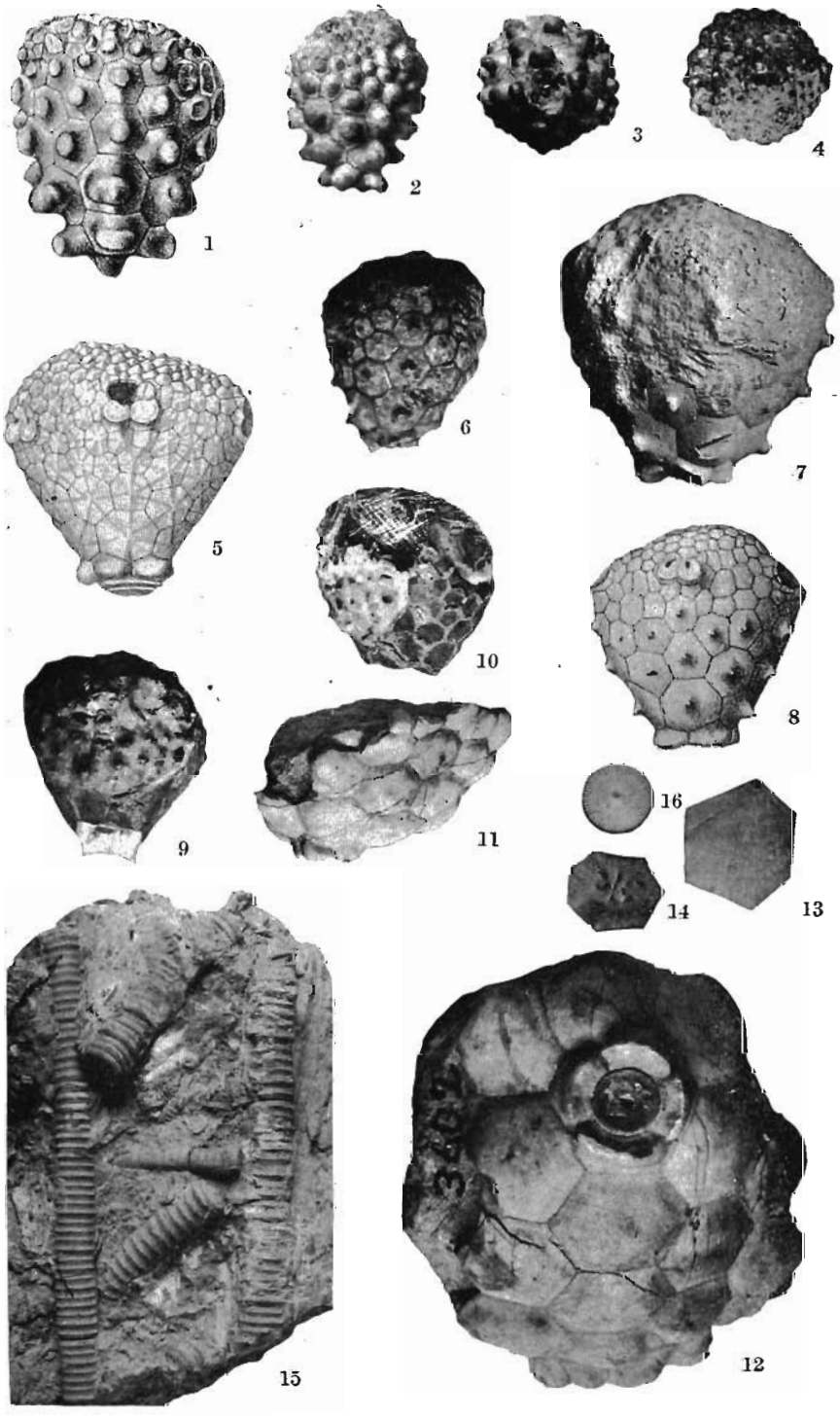
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PLATE XXXVIII.

Figs. 1-3. *Stereocrinus triangulatus* Barris.

1, 2. Basal and side views of the type, after Wachsmuth and Springer. 3. An imperfect specimen preserving the basals, the radials, and a few plates beyond them. The characteristic markings of the species are well shown. North of Iowa City. (T. J. Fitzpatrick Coll.)

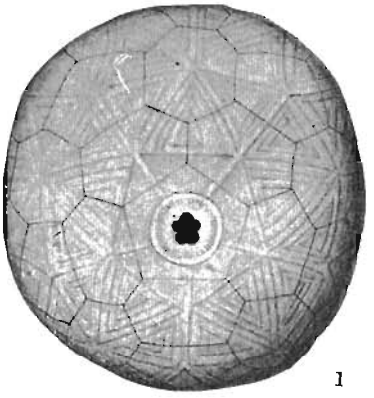
Figs. 4, 5. *Stereocrinus littletonensis* Thomas.

Basal and lateral views of the holotype. Littleton, S. Calvin. (U. I. C. 3627.)

Figs. 6-12. *Megistocrinus farnsworthi* White.

6-9. Posterior, left anterior, tegminal, and basal views of the better of the two cotypes. 10, 11. Tegminal and basal views of the other cotype which is crushed but preserves a portion of the stem; orientation uncertain. Both specimens from near Iowa City, P. J. Farnsworth. (U. I. C. 3621 and 3622.)

12. Basal view of a somewhat damaged but typical calyx. North of Iowa City, Walter V. Searight. (U. I. C. 3753.)



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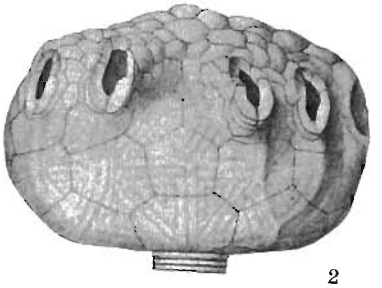

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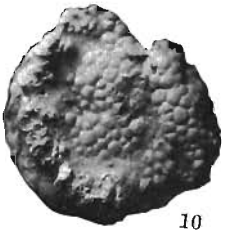

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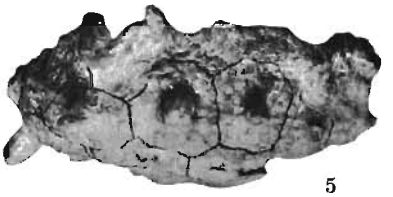

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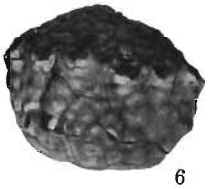

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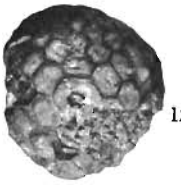

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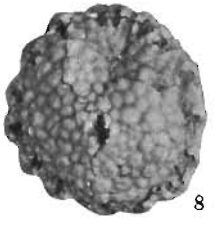

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PLATE XXXIX.

Figs. 1-5. *Megistocrinus robustus* Thomas.

1-3. Right lateral, tegminal, and basal views of the type specimen. Solon, S. Calvin. (U. I. C. 3604.)

4, 5. Right posterior and basal aspects of a smaller specimen. Solon, S. Calvin. (U. I. C. 3614.)

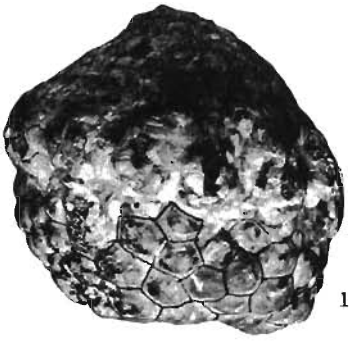
Figs. 6, 7. *Megistocrinus fitzpatricki* Thomas.

6. Basal view of the type.

7. View from the anal side of another specimen which lacks the tegmen. Both specimens from Linder's Boathouse. (Fitzpatrick Coll.) See also Plate XLVI, figures 10, 11.

Fig. 8. *Megistocrinus concavus* Wachsmuth.

Basal view of a typical specimen introduced for comparison. From Devonian at Alpena, Michigan. (U. I C. 3671.)



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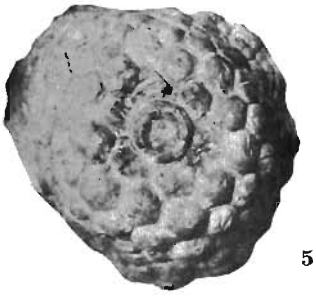

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PLATE XL.

Figs. 1-8. *Megistocrinus clarkei* Thomas.

1, 2. A left anterior and an anterior view of the type specimen preserving parts of six of the arms and a piece of the stem. (U. I. C. 3668.)

3. A much silicified individual with a somewhat higher tegmen than on average specimens. (U. I. C. 3626a.)

4. Tegminal view of an individual showing the *Platyceras* scar and the anal aperture. A part of the parasite's shell remains along the upper border of the scar as seen in the figure. (U. I. C. 3669.)

5, 6. Tegminal views of two other specimens showing the *Platyceras* scars. (U. I. C. 3626 and 3667.)

7, 8. Two views of a specimen preserving the shell of the gastropod, *Platyceras inoptatum* Thomas. The adaptation of the margin of the shell to the irregularities of the tegmen is remarkable. (U. I. C. 3623.)

All the specimens from Waterloo. Collected by Mrs. David Brant. See also Plate XLVI, figure 9.


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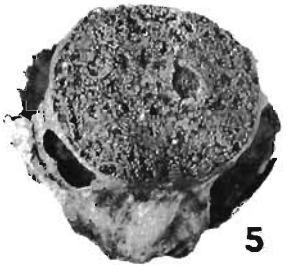
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PLATE XLI.

Fig. 1. *Megistocrinus latus* Hall.

Basal aspect of a calyx which lacks the arms and the tegmen. The anterior side is wider than the posterior in this individual. Iowa City, L. P. Elliott. (U. I. C. 3603.) See also Plate XLV, figure 3.

Figs. 2-4. *Megistocrinus nodosus* Barris.

2. Lateral aspect of a very perfect specimen which preserves a part of the stem. 3. Tegminal view of same specimen. 4. Lateral view of a smaller and younger individual. Both specimens from Alpena, Michigan, W. H. Barris. (Mus. Davenport Acad. Sci.)

Figs. 5-23. *Megistocrinus pernodosus* Thomas.

5. A set of united basals. Brandon, A. O. Thomas. (U. I. C. 3737.) 5a. Diagram of basals, x3; proportions after figure 5, by O. T. Walter. 6, 7. Lateral and dorsal views of an anchylosed set of BB to which is attached a nodose radial, x2. Brandon, A. O. T. (U. I. C. 3726.) 8-10. Side views, x2, of three plates showing height of the nodes and the constriction toward their bases; number 9 is from a curved part of the calyx wall. 11-17. Outer or dorsal view of several plates illustrating the extent to which the nodes cover their surfaces. All x2. Brandon, A. O. Thomas and M. A. Stainbrook. (U. I. C. 3727-3736.) 18-23. Stem segments from the type locality assumed to belong to this species. Natural size. Brandon, A. O. Thomas. (U. I. C. 3745-3750.)

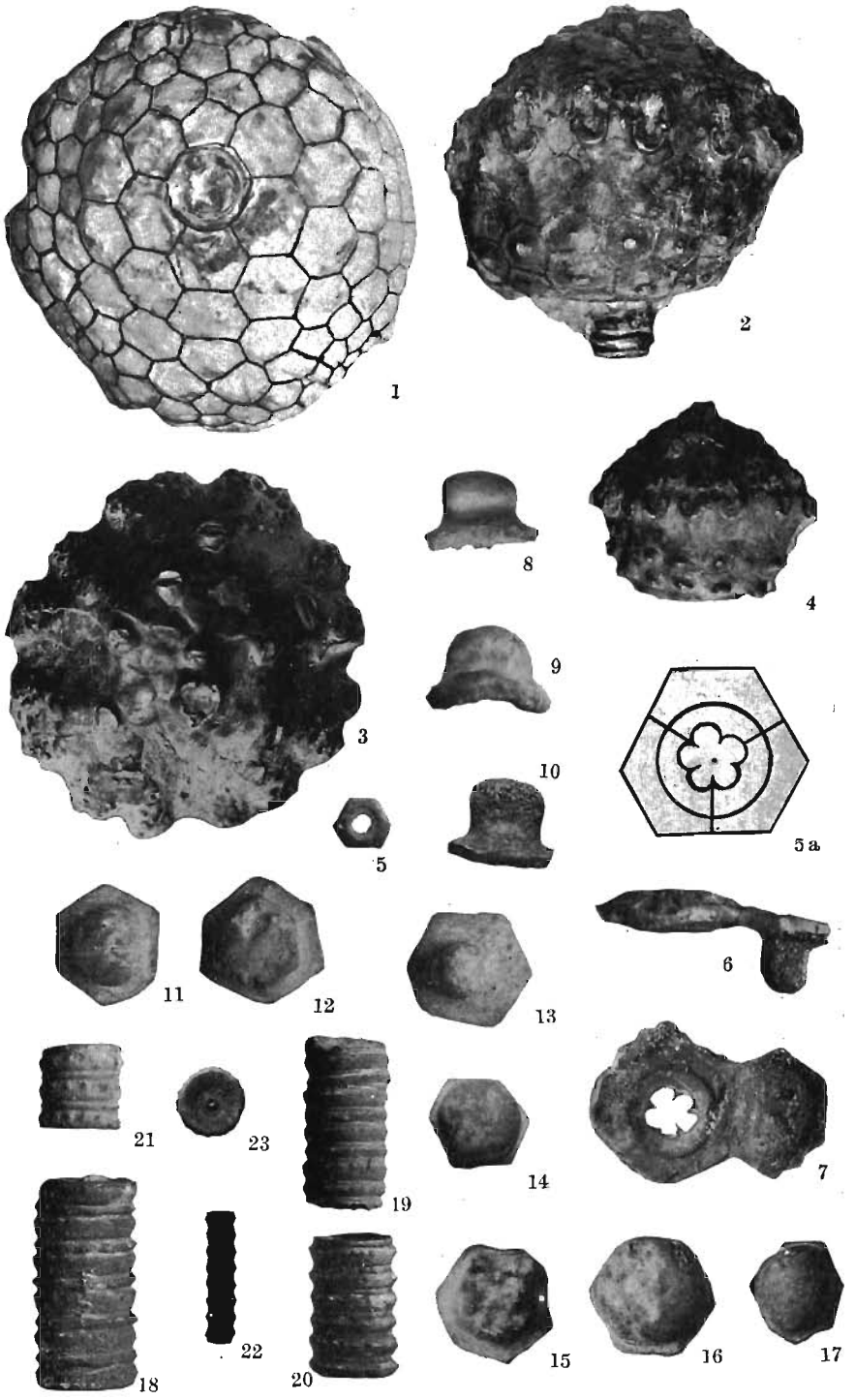
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PLATE XLII.

Fig. 1. *Hexacrinus occidentalis* Wachsmuth and Springer. Anterior view of the type specimen after Wachsmuth and Springer. Davenport, W. H. Barris. (Museum Davenport Academy Science.)

Figs. 2-9. *Hexacrinus springeri* Thomas.

2. A portion of an arm preserving the pinnules, assumed to belong to this species. Type locality, C. H. Belanski. (U. I. C. 3722.) 3-5. Basal, left anterior, and anal views of the type specimen, the last figure about x2. South of Nora Springs, C. H. B. (U. I. C. 3631.) 6. A large radial preserving a part of IBr_1 in the facet, x2. Type locality, A. O. Thomas. (U. I. C. 3723.) 7-9. A radial and two IBr arranged in natural sequence. Along Shell Rock river, C. H. B. (U. I. C. 3724.) Twice natural size.

Figs. 10-13. *Hexacrinus iowensis* Thomas.

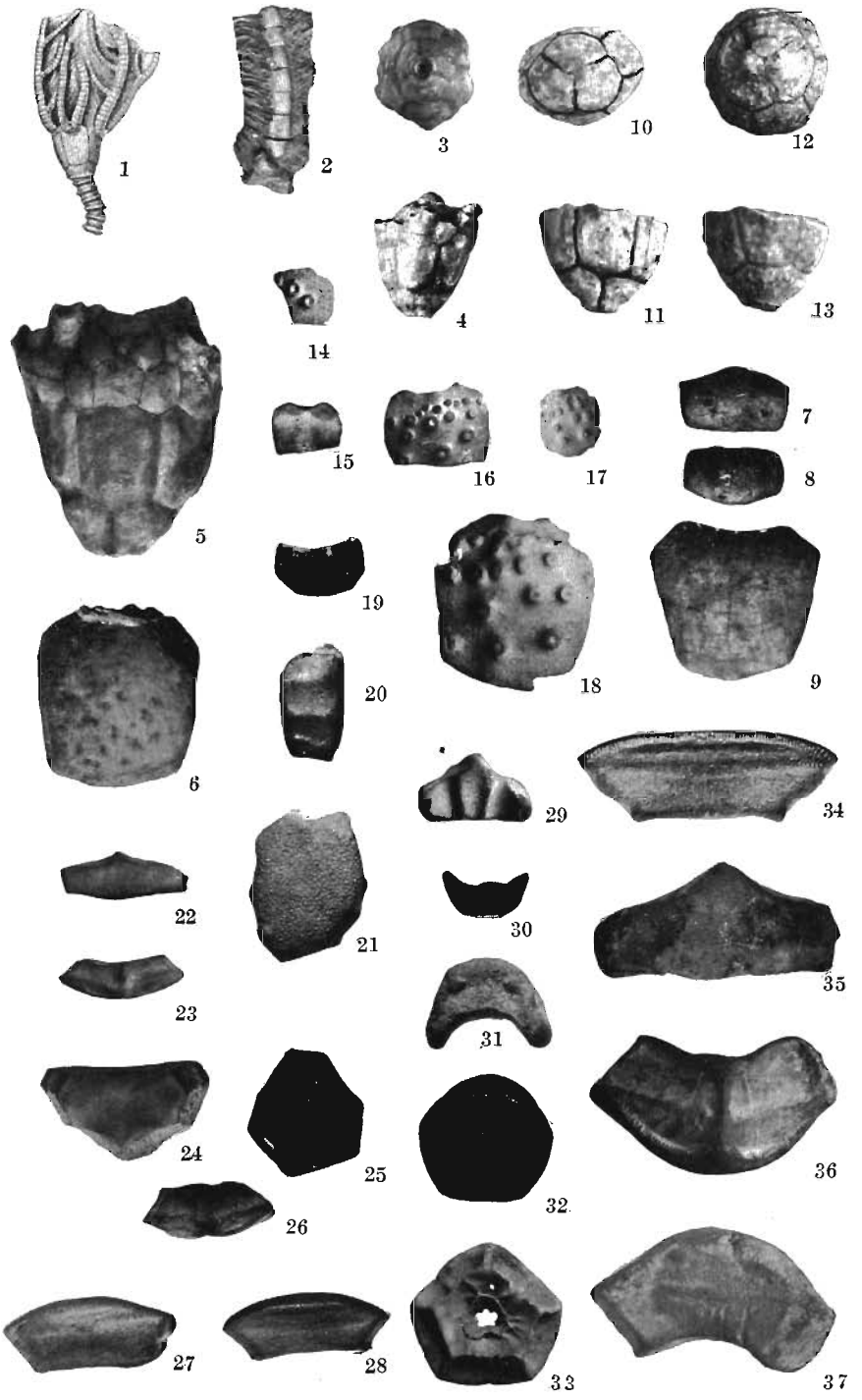
10, 11. Basal and side views of the type. (U. I. C. 3708.) 12, 13. Basal and side views of the cotype. Note that one basal plate is fully as large as the other two combined. (U. I. C. 3707.) Both from near Nora Springs, C. H. Belanski. All the figures about x2.

Figs. 14-18. *Arthracantha mamelonifera* Thomas.

14. Broken radial plate. Independence, S. Calvin. (U. I. C. 3721.) 15, 16. Ventral and dorsal views of the type, the latter view x2. It is an imperfect radial plate. Brandon, A. O. Thomas. (U. I. C. 3720.) 17, 18. Two views of a radial plate, the second view about x2.5. Brandon, M. A. Stainbrook. (U. I. C. 3719.)

Figs. 19-34. *Clidochirus iowensis* Thomas.

19. Dorsal view of a IIBr. 20, 21. Lateral view, showing thickness and facets, and a dorsal view showing granular surface; the views are x2 and x3 respectively. The plate is an interradial probably from the anal series. (U. I. C. 3705a.) 22, 23. Dorsal and distal views of IAx. 24. Ventral or inner view of a radial, x2. (U. I. C. 3700b.) 25. Ventral view of a basal x2, orientation uncertain. (U. I. C. 3674d.) 26. Distal view of a IAx. 27, 28. Proximal aspect of two IBr plates, x2 (U. I. C. 3701a and 3701b.) 29. Ventral view of a IIAx or IIIAx, x3. (U. I. C. 3672a.) 30, 31. Distal and proximal views of two IIBr showing shape, curvature, and articulation, x2 and x3 respectively. (U. I. C. 3704e and 3704c.) 32. IBB showing extension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beyond the column, the bounding rim, flat stem facet, and lumen, x3. (U. I. C. 3673f.) 33. A set of IBB showing the trilobate funnel, articulating facets, and other features, x3. (U. I. C. 3673b.) 34. Proximal view of a IBr; note its thickness, articulating grooves, and milled edge, x3; figure 27, Plate XLIII is the same specimen. (U. I. C. 3701c.)

Rockford, Bird Hill, and Hackberry Grove, C. H. Belanski and A. O. Thomas.

Figs. 35-37. *Clidochirus maximus* Thomas.

Dorsal, distal, and proximal views of the type specimen, about x2. Brandon, A. O. Thomas. (U. I. C. 3706.)

PLATE XLIII.

Figs. 1-9. *Hexacrinus springeri* Thomas.

A full complement of basals and radials found as scattered plates, about x2. Nora Springs, C. H. Belanski. (U. I. C. 3725.) See also Plate XLII, figs. 2-9.

Figs. 10-44. *Clidochirus iowensis* Thomas.

10-14. A series of IIBr, or possibly IIIBr, two of them are Ax. (U. I. C. 3704a-e.)

15-19. A series of IIBr. (U. I. C. 3703a-e.)

20-24. A series of IAx. (U. I. C. 3702a-e.)

25-29. Five IBr. (U. I. C. 3701a-e.)

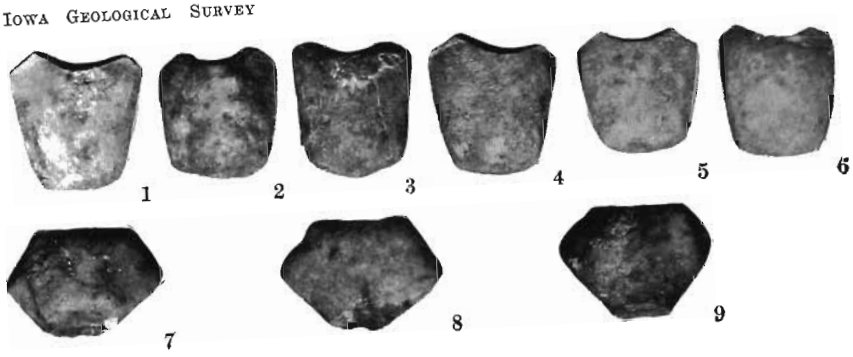
30, 34. Two iBr plates; these have four facets on each side, the distal depression is not a true facet. Figures 20, 21, Plate XLII, are illustrations of the same specimen as figure 34. (U. I. C. 3705a and 3705b.)

31-33. Three radial plates. (U. I. C. 3700a-c.)

35-39. A series of basals showing variation in shape and size. (U. I. C. 3674a-e.)

40-44. Five sets of IBB, showing the trilobate funnel, the pentalobate lumen, and the bounding ridges of the facets. (U. I. C. 3673a-e.)

These thirty-five plates and combined IBB are offered as the type material of this species. The selection is made from a series of several hundred plates collected by C. H. Belanski and the author at Bird Hill and vicinity. All are about x2.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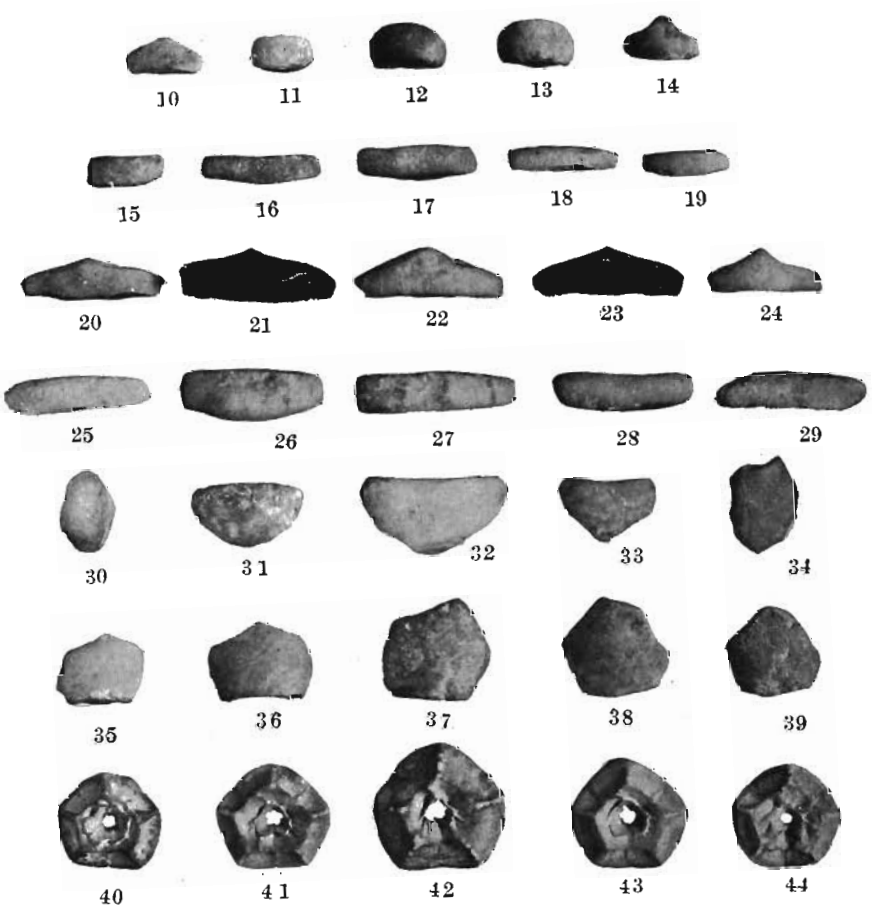
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PLATE XLIV.

Figs. 1-5. *Dactylocrinus stellatimbasalis* Thomas.

1. A view of the right posterior ray, x3.6, showing the bifurcations. 2-4. Right posterior interradial, anal, and basal views, about x2.5; the last shows the excavate base partly filled by the stem; note also the star-shaped figure made by the basals. 5. Anal view, x1.5. All are views of the holotype. (U. I. C. 3709.) Near Bird Hill, C. H. B.

Figs. 6, 7. *Dactylocrinus concavus* (Rowley).

Posterior and basal views of one of Rowley's cotypes from Devonian, Callaway Co., Mo. Figures copied for comparison from Plate xli, figures 7a and 7c, Crinoidea Flexibilia.

Fig. 8. *Euryocrinus barrisi* Springer.

Right anterior view of a specimen from Buffalo. Collected by W. H. Barris and now in the Springer Collection. The species occurs also near Alpena, Michigan. After Springer, Crin. Flex., Pl. xl, fig. 3.

Fig. 9. *Synbathocrinus matutinus* Hall.

A view of the type specimen after Hall in Geol. Surv. Iowa, vol. I, part ii, Plate I, fig. 2, 1858. Buffalo.

Fig. 10. *Taxocrinus interscapularis* Hall

A view of the type after Springer, Crin. Flex. Plate lii, fig. 6. Buffalo. Specimen in Univ. of Ill. collection.

Figs. 11-16. *Cyathocrinus rockfordensis* Thomas.

11, 12 and 15, 16. Ventral and dorsal views respectively of two radials showing the facets and the ambulacral notches, about x2. Near Rockford, A. O. Thomas and C. H. Belanski. (U. I. C. 3759 and 3760.)

13, 14. Two other specimens, about x2. (U. I. C. 3757 and 3758.)

Figs. 17, 18. *Eutaxocrinus gracilis* (Meek and Worthen).

Two views of the type; University of Illinois collection. Buffalo, A. H. Worthen. After Springer, Crin. Flex., Plate xlix, 8a, 8b.

Fig. 19. *Poteriocrinus buffaloënsis* Worthen.

Anterior view of the type specimen. Buffalo, A. H. Worthen. After Geol. Surv. Ill. vol. viii, Plate 12, fig. 1.

Figs. 20, 21. *Deltacrinus barrisi* (Worthen).

Two views, about x2, of an imperfect specimen, showing stem facet and suture lines. Davenport, W. H. Barris. (Museum Davenport Academy of Science.)

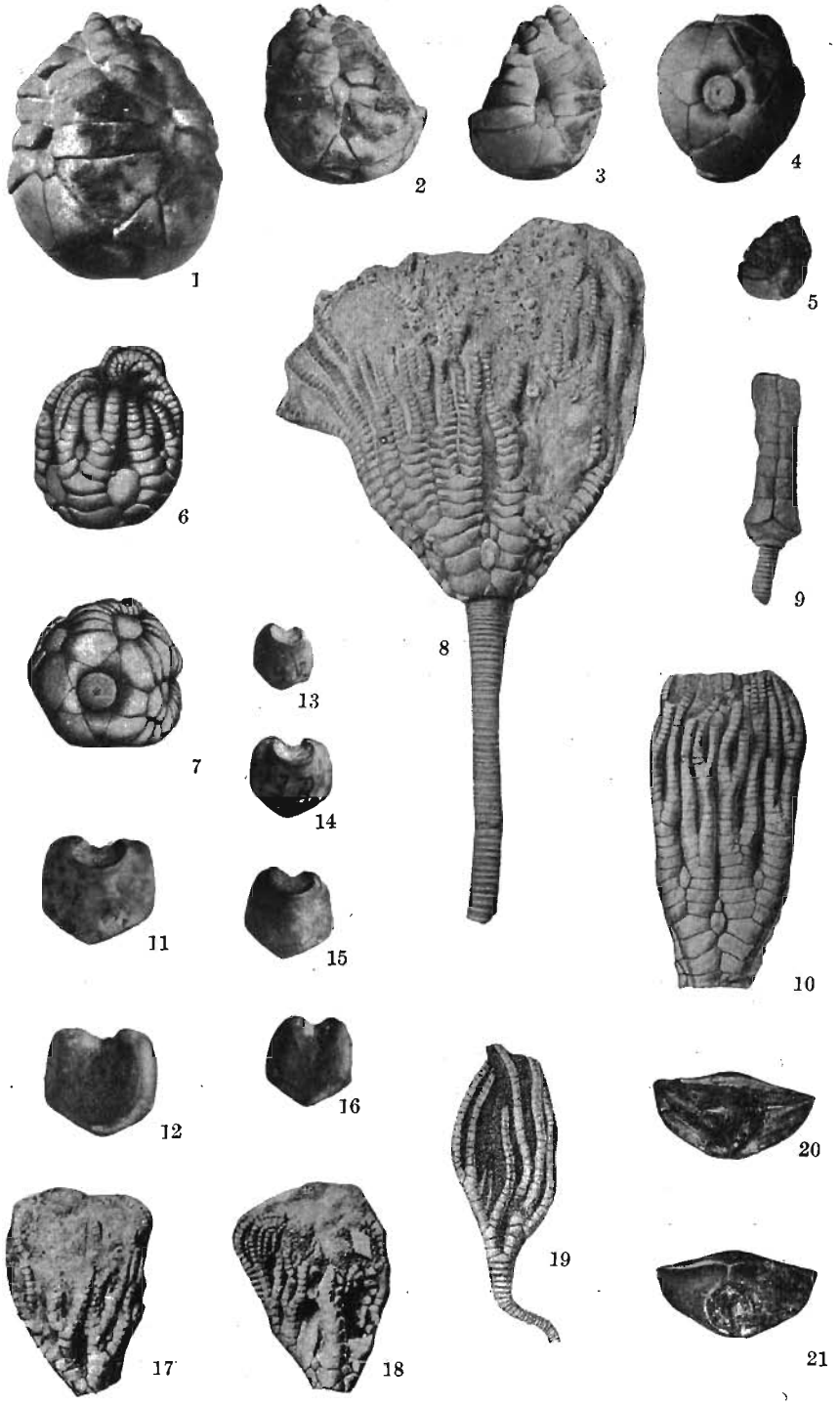
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PLATE XLV.

Fig. 1. *Decadocrinus vintonensis* Thomas.

The type specimen preserving the arms and a piece of the stem, about x2. Near Vinton, E. P. Whipple. (U. I. C. 3630.)

Fig. 2. Crinoid preserving arms and pinnules but split through in such a way as to destroy the calyx. *Megistocrinus* beds (?) near Solon, Lloyd North. (U. I. C. 3761.)

Fig. 3. *Megistocrinus latus* Hall.

A specimen preserving nearly three cycles of the smooth plates characteristic of this species. Upper levels of Linwood Quarry, below Davenport, U. A. Hauber. (Museum of St. Ambrose College.) See also Plate XLI, figure 1.

Figs. 4-6. Crinoid stem fragments.

Number 6 evidently is a large segment from a stem similar to number 4; note the hublike protrusion made up of a number of very thin columnals. Number 5 is remarkable for the rows of elongate nodes along the peripheries of its thin columnals. Bird Hill, Lime Creek shale, A. O. Thomas. (U. I. C. 3764 a, b, c.)

Fig. 7. *Megistocrinus merrilli* Thomas.

Basal view showing three cycles of plates. Note the low nodes on the IBr and iBr plates. Orientation assumed to be correct. One and one-fourth miles southwest of Brandon, M. A. Stainbrook. (U. I. C. 3762.)

Fig. 8. Crinoid stem, joint face x2.2. Compare *Megistocrinus.*

Common in *Hexacrinus* zone south of Nora Springs, C. H. Belanski. (U. I. C. 3739d.)

Figs. 9-10. Crinoid stems showing joint faces x3.

The joint face is a rounded pentagon in outline. Floors of the sectors are slightly depressed and the arrangement of the crenellae is quite unique. Lumen pentagonal.

Associated with the plates of *Hexacrinus springeri,* south of Nora Springs, C. H. Belanski and A. O. Thomas. (U. I. C. 3715c, d.)

Fig. 11. Crinoidal limestone.

Devonian, Cerro Gordo county, A. O. Thomas. (U. I. C. 3765.)

Fig. 12. *Euryocrinus* cf. *barrisi* Springer.

Fragment of a calyx from a ravine below Davenport, U. A. Hauber. (U. I. C. 3763.) See also Plate XLIV, fig. 8.


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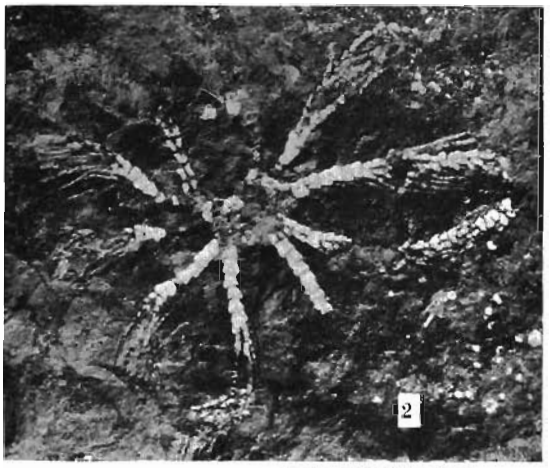
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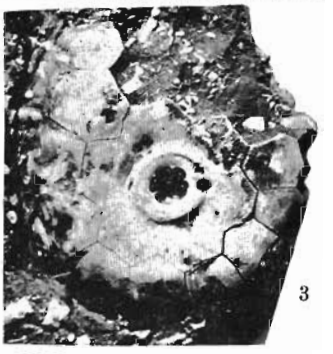
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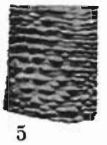
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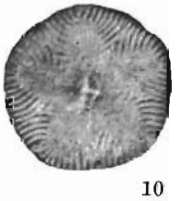
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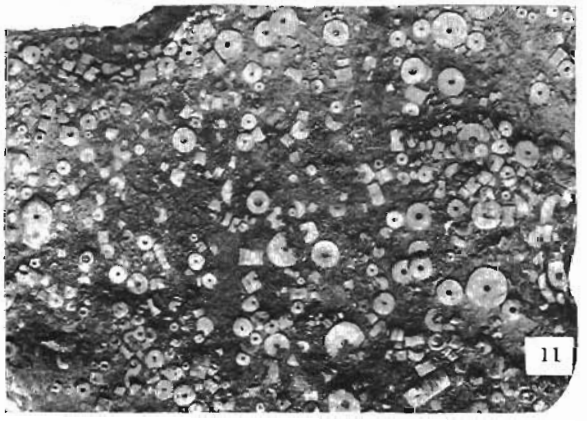
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PLATE XLVI.

Figs. 1-5. *Agelacrinites hanoveri* Thomas.

1. A large specimen, peripheral wall nearly intact, thecal plates and rays only partly preserved. (U. I. C. 3523a.)

2. A smaller specimen on same substratum as number one; imperfectly preserved. (U. I. C. 3523b.)

3. A small individual showing two solar and three contrasolar rays and the position of the anal pyramid; thecal plates lost, cover plates obscure, x2. (U. I. C. 3522.)

4. Specimen preserving thecal and wall plates showing imbrication; cover plates of arms can be made out in one or two places, x2. (U. I. C. 3521.)

5. A sector of the last tilted to show plates of the peripheral wall, x3.5.

Fig. 6. *Agelacrinites* sp.

A specimen attached to the shell of a brachiopod. Thecal and cover plates present but jumbled out of position. Brandon, M. A. Stainbrook. (U. I. C. 3524.)

Fig. 7. Crinoidal limestone.

A polished fragment from a zone near Linder's Boathouse, left bank of Iowa river, about six feet above low water as controlled by the Coralville dam, A. O. Thomas. (U. I. C. 3767a.)

Fig. 8. Slab on which are a number of long, slender, pinnulate, and dichotomously branching portions of the arms of a crinoid; probably one of the fistulates. The objects along the middle of the figure are apparently the elements of the ventral sac. Schmidt's quarry, Davenport, W. H. Norton. (U. I. C. 3768.)

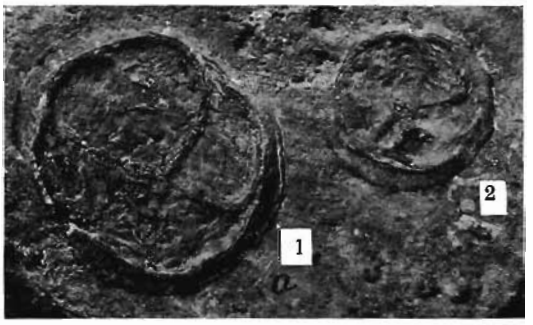
Fig. 9. *Megistocrinus clarkei* Thomas.

Part of the dome of a specimen on which the plates have been separated by crystalline expansion of the interior, about x2. Note the granular surfaces. Waterloo, Mrs. David Brant. (U. I. C. 3769.) See also Plate XL, figs. 1-8.

Figs. 10-11. *Megistocrinus fitzpatricki* Thomas.

10. Enlargement of a part of the base of a calyx to show the raised sutures and central nodes.

11. Enlarged view of a suture on same specimen showing the arrangement of the granules into ridgelets at right angles to the suture line. Type specimen. (Fitzpatrick Coll.) See also Plate XXXIX, figures 6, 7.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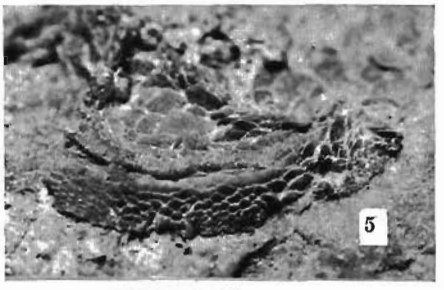
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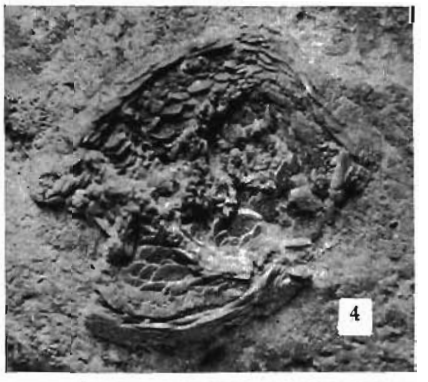
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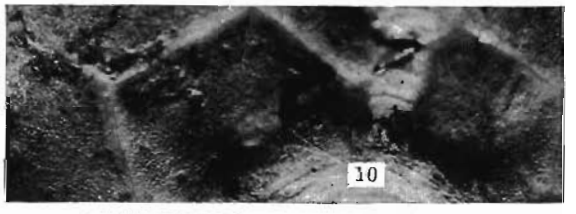
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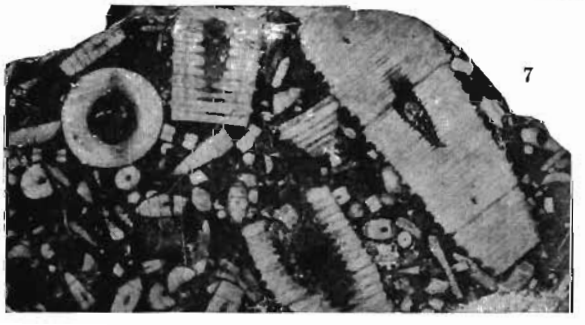
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PLATE XLVII.

Figs. 1-7. *Nortonechinus welleri* Thomas.

Fig. 1. The type specimen natural size. See enlargement, Fig. 7, also text figure 74. (U. I. C. No. 3044.) Rockford, C. H. Belanski.

Fig. 2. A part of the inner surface of the type specimen, x3.3. The brace, showing its lower surface, on the upper part of the figure is larger than any other found; its length is 11.5 mm. The object on the right side of the brace is thought to be the end of a compass. In the lower part of the figure is a half pyramid showing the retractor muscle depression; it is close to 12 mm. long. A chain of close-set ambulacral plates lies between the pyramid and the brace. They are seen from the inner side. Note the peculiar "hooks" which are a part of the imbrication, also the pore-pair.

Figs. 3-6. Four braces found loose among plates and spines, vicinity of Rockford. Figures are about x2; all are seen from the upper side. (They are U. I. C. Nos. 3047, 3048a, 3048b, and 3052a, respectively.)

Fig. 7. The type specimen about x3.3. A little of the right and left edges have been cut off in the illustration. Note the telescoping of the plates near the center of the specimen—due to accident in preservation—the spines clinging to the upper left hand corner, the diagonal arrangement of the plates, the vertical columns, the imbrication, the miliary spines, the scrobicular tubercles, and other features.

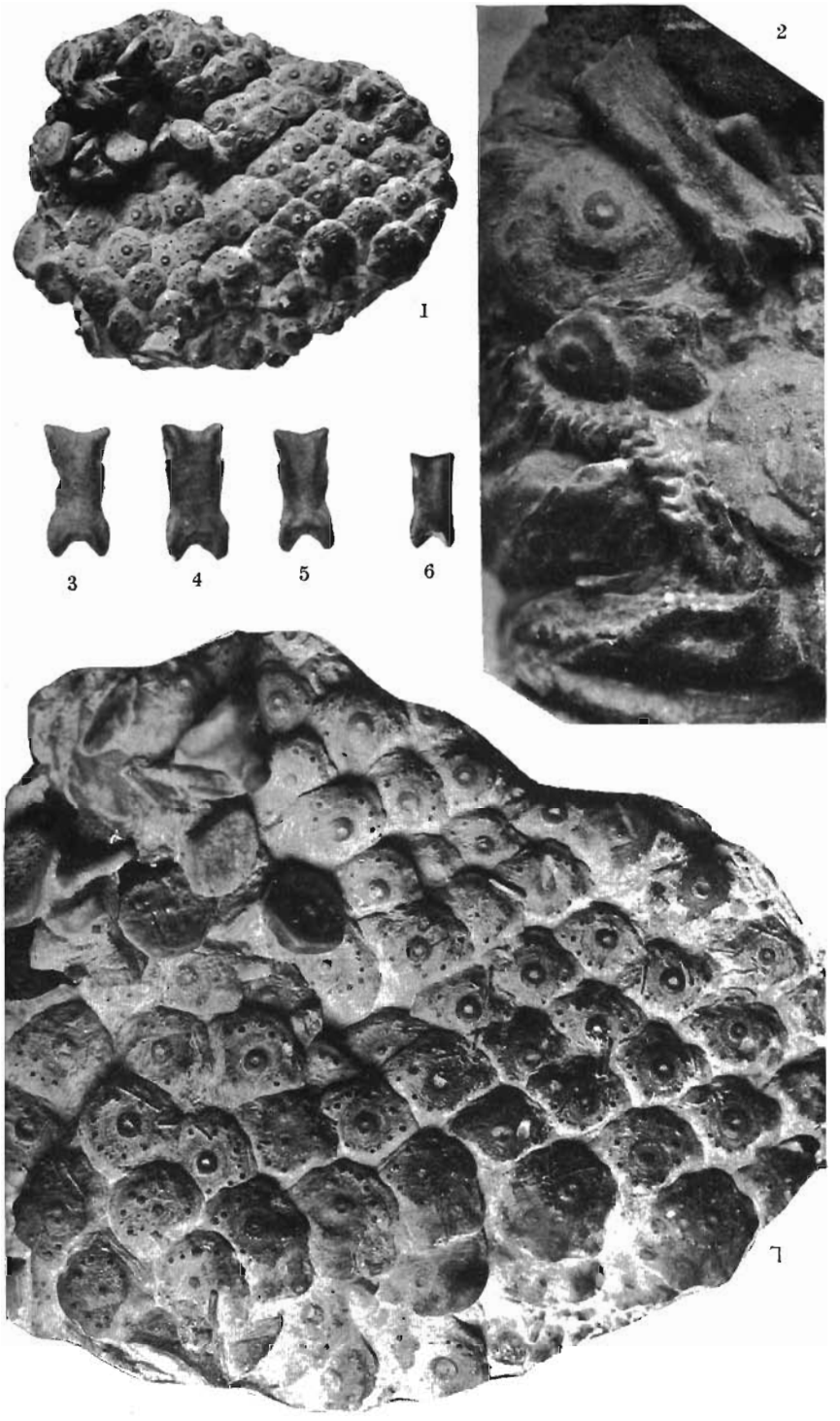
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PLATE XLVIII.

Nortonechinus welleri Thomas.

Plates and spines. All from the type localities west, northwest, and southwest of Rockford and a few from Hackberry Grove and vicinity. Collected by C. H. Belanski and A. O. Thomas.

Fig. 1. A row of typical spines seen from the side.

Fig. 2. Apical view of seven spines; the two on the left are round, the one on the right rounded polygonal.

Fig. 3. Basal view of seven specimens showing acetabulum.

Figs. 4-18. A lot of spines, x2. 4-7 show the stout shafts, the facets, and short bases, 8, 9 are acetabular views, 10 is a stout spine of unusual appearance, with a rudely circular termination, 11-16 illustrate the polygonal, somewhat radially pustulate, nearly flat apices of typical spines. Note that some are five- and that some are six-sided. 17, 18 are spines in which the apical face is oblique to the axis of the shaft. (Selected from a lot of 20, U. I. C. 3060.)

Figs. 19-20. Apical view of two spines nearly quadrangular in outline, x2. (U. I. C. 3061a, b.)

Fig. 21. A spine terminating in a spatulate, three-vaned apex, x2. (U. I. C. 3061c.)

Fig. 22. A spine with rounded polygonal apex, x2. (U. I. C. 3061d.)

Figs. 25-28. Apical views of four spines with circular or subcircular terminations, x2. Note the tendency toward a radial disposition of the ridglets and pustules; number 27 resembles the coronet-bearing apex of a *Xenocidaris* spine but has no central spinule and its shaft, figure 33, is much stouter. (U. I. C. 3062 a-d.)

Figs. 29-35. Lateral views of numbers 19, 20, 25-28, and 22, but slightly larger; 19 is same as 29, and so forth.

Fig. 36. A group of eighteen plates illustrating variety in outline and other features.

Figs. 37-49. A number of plates, x2. Number 39 is well above normal size; note that some of its sutures are curved toward the center; number 47 is of normal length but is only approximately one-third the normal width; numbers 48, 49 illustrate the adapical bevel of the inner surface bringing out the three areas modified, one for each plate concerned in the aboral imbrication. (U. I. C. 3095 a-m.)

Note.—The proportion of roundly terminated spines shown on this plate and the next compared to the number of polygonal spines shown is much greater than their relative abundance in the field.

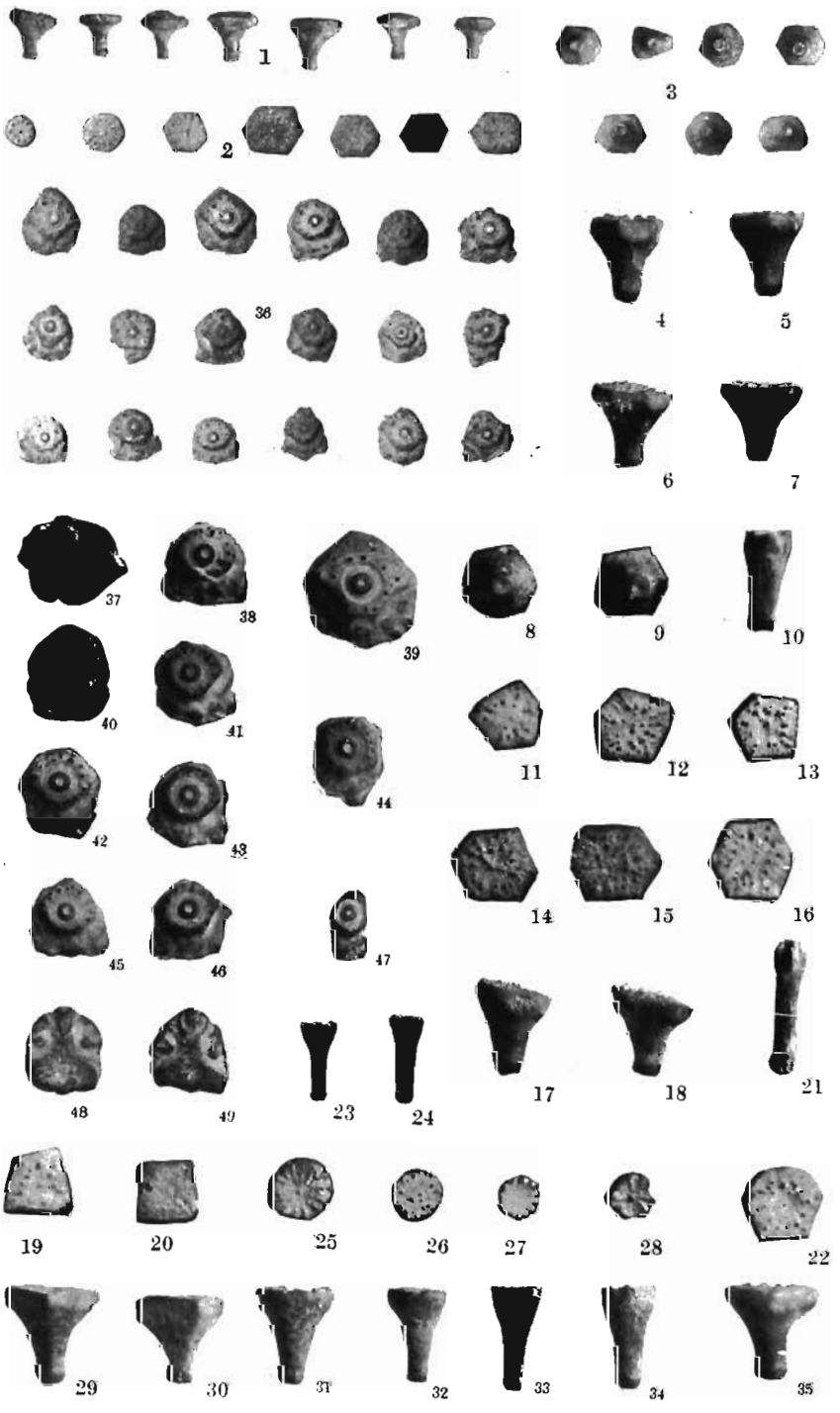
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PLATE XLIX.

Figs. 1-6. *Nortonechinus welleri* Thomas.

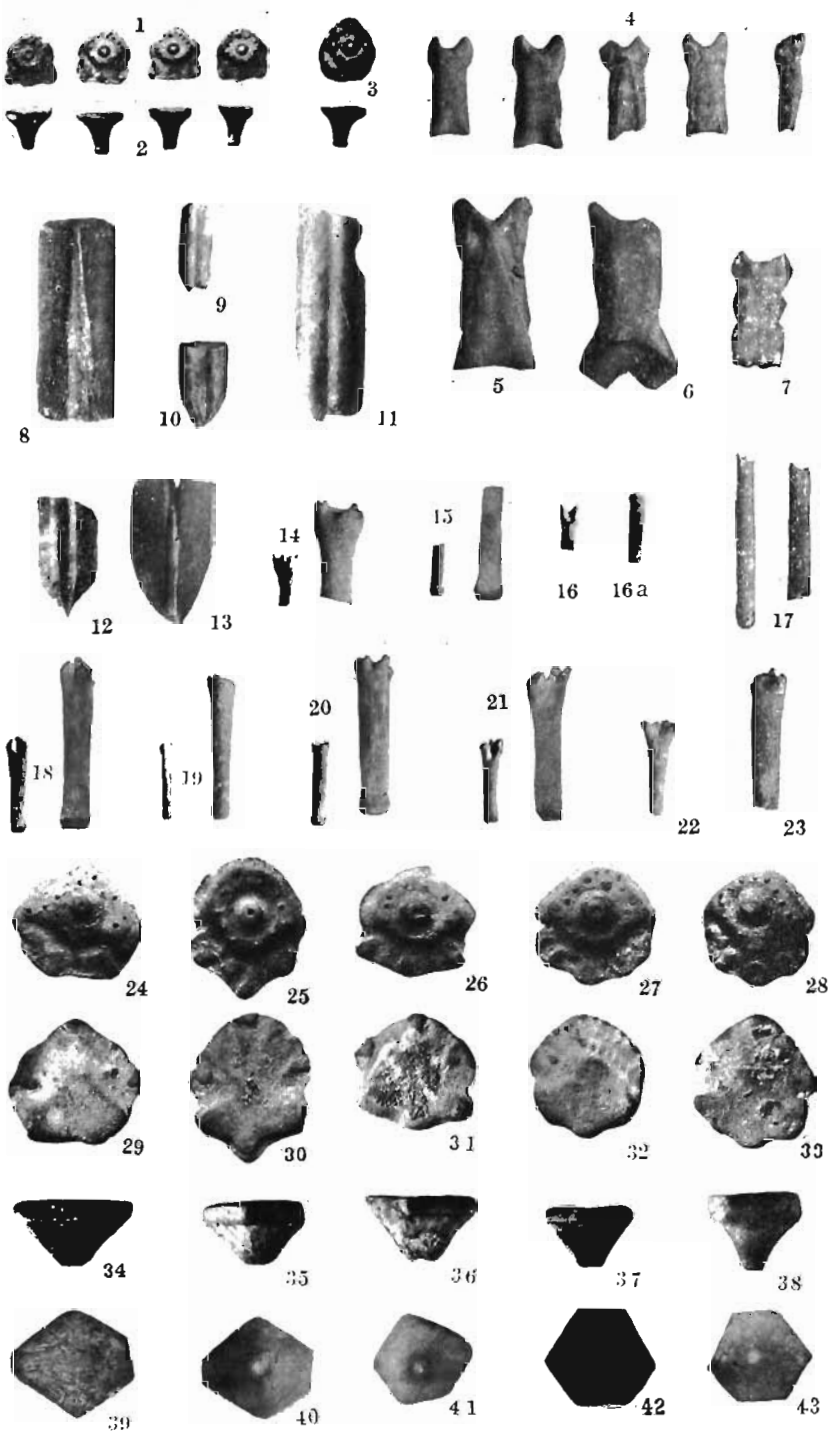
All collected by C. H. Belanski and A. O. Thomas in the vicinity of Rockford unless otherwise stated.

1, 2. Four interambulacral plates with well developed adoral flanges (U. I. C. 3054 a-d) and four typical primary spines. (U. I. C. 3055 a-d.) This is the lot of plates and spines whose measurements are given in the text. 3. An interambulacral plate and a primary spine. This pair is the basis of the drawings by Miss Horn, see text figure 78. Hackberry Grove, W. H. Norton. (U. I. C. 3056 a, b.) 4. An illustration of five braces, about x2; the two on the left are seen from above, the one on the right is seen from the side, the other two from below. The middle one is partly broken along calcite cleavage. (Left to right they are U. I. C. 3053a, 3048b, 3053b, 3048a, and 3053c.) 5. A nearly perfect brace seen from below, x3.3. (U. I. C. 3057.) 6. Brace seen from above, x3.3; same as third specimen of figure 4.

Fig. 7. Brace from the lantern of a modern sea urchin, *Dorocidaris papillata,* x3.3, introduced for comparison. Key West, 200 fathoms, S. U. I. Bahama Expedition. (U. I. C. 3058.)

Figs. 8-23. *Nortonechinus welleri* Thomas.

8. Part of tooth seen from within, showing the distal widening of the median groove, x3.6. (U. I. C. 3046a.) 9. A broken tooth, narrower than the last, face view, showing the ridges on either side of the median depression and the submarginal grooves, about x1.5. (U. I. C. 3045a.) 10. Tip of a tooth, face view, x2.3. (U. I. C. 3046c.) 11. Same as figure 9 but x3.8. 12. Tip of a tooth preserving the sharp point and the small lateral denticles, about x3.4. 13. Part of a tooth near the tip seen from within; same as figure 10 but x3.5. 14-23. A number of spines with very slightly expanded apices and which terminate in a number of prongs. 14. Two views of the apical portion of a spine, irregularly campanulate, ending in six spinules, x1 and x2. (U. I. C. 3052b.) 15. Proximal part showing base and part of shaft, x1 and x2. (U. I. C. 3052d.) 16. A bit of the apical part of a spine with very long prongs, one or two broken off. (U. I. C. 3052a.) 16a. A nearly cylin-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drical shaft ending in five blunt spinules. (U. I. C. 3052c.) 17. Two slender spines, each ending in three sharp points, x3.3. (U. I. C. 3059 a, b.) 18. A long stout spine, five-pronged, x1 and x2. (U. I. C. 3051a.) 19. A long and comparatively slender four-pronged spine, x1 and x2. (U. I. C. 3051d.) 20. A long stout example, five-pronged, x1 and x2. (U. I. C. 3051c.) 21. A seven-pronged spine, tips of prongs and the base lost, x1 and x2. (U. I. C. 3051b.) 22. An incomplete specimen with short spinules, x2. 23. Same as figure 16a, about x2.

Figs. 24-33. *Nortonechinus welleri latus* Thomas.

Outer and inner views of five typical interambulacral plates; figure 29 is inner view of 24, 30 of 25, and so forth, x2. West of Bird Hill in Cerro Gordo county, C. H. Belanski and A. O. Thomas. (U. I. C. 3049 a-e.)

Figs. 34-43. *Nortonechinus stainbrooki* Thomas.

Lateral, apical, and basal views of a number of the short squatty spines of this species, x2. Type specimens. Brandon, M. A. Stainbrook. U. I. C. 3093 a-f; figs. 34, 39, 40= 3093a; 35, 42, 43= 3093b; 41= 3093f; 37= 3093d; 38= 3093e; and 36= 3093c.) See also text figure 80.

PLATE L.

Figs. 1-25. *Xenocidaris americana* Thomas.

1. A left hemipyramid showing tooth slide, about x2. Rockford, C. H. Belanski (U. I. C. 3073.) 2. A complete and fairly typical spine, about x2 (U. I. C. 3074.) 3. A large but incomplete spine, about x2 (U. I. C. 3075.) 4. Apical expansion with prominent coronet and fluted sides, about x2 (U. I. C. 3076.) 5-8. Typical spines showing expansion and fluting, about x2 (U. I. C. 3077-3080.) 9-15. Apical views of a series to show the circular or subcircular coronets and the central pustule or pustules, about x2. Number 11 is same as number 6. (U. I. C. 3081-3086.) 16. Iamb plate, x2 (U. I. C. 3087.) 17, 18. Lateral view of spines showing fluting, about x2 (U. I. C. 3088, 3089.) 19, 20. Same as figures 4 and 3 but x2.3. 21-24. Apical views of specimens to show result of lateral compression, scarcely noticeable in first two, the third with two sides developed, the fourth nearly a complete polygon, about x2 (U. I. C. 3068-3071.) 25. A lot selected at random to show general features; one is nearly complete, from most of the others the slender part of the shaft is broken away (U. I. C. 3067.)

Figs. 26-35. *Nortonechinus* (*?*) *owenensis* Thomas.

26. Basal and apical parts of spines; also a hemipyramid, enlarged. 27. Same as figure 26, natural size. Near T. E. Wagner's home, C. H. Belanski (U. I. C. 3063, 3064 a-e, left to right.) 28, 29. A pair of worn and partly broken plates. Type locality, C. H. Belanski (U. I. C. 3065 a, b.) 30-35. A number of typical plates, x2. 30 shows typical *Nortonechinus* bevel; breakage and wear have obliterated most of the features. Type locality, C. H. Belanski (U. I. C. 3066 a-f.)

Fig. 36. *Devonocidaris jacksoni* Thomas.

Part of slab 3001, x4.5, to show parts of three teeth, also plates and spines. At end of the arrow near center of figure is a genital plate with the madreporite; see Pl. LI, figure 25. Bird Hill, A. O. Thomas.

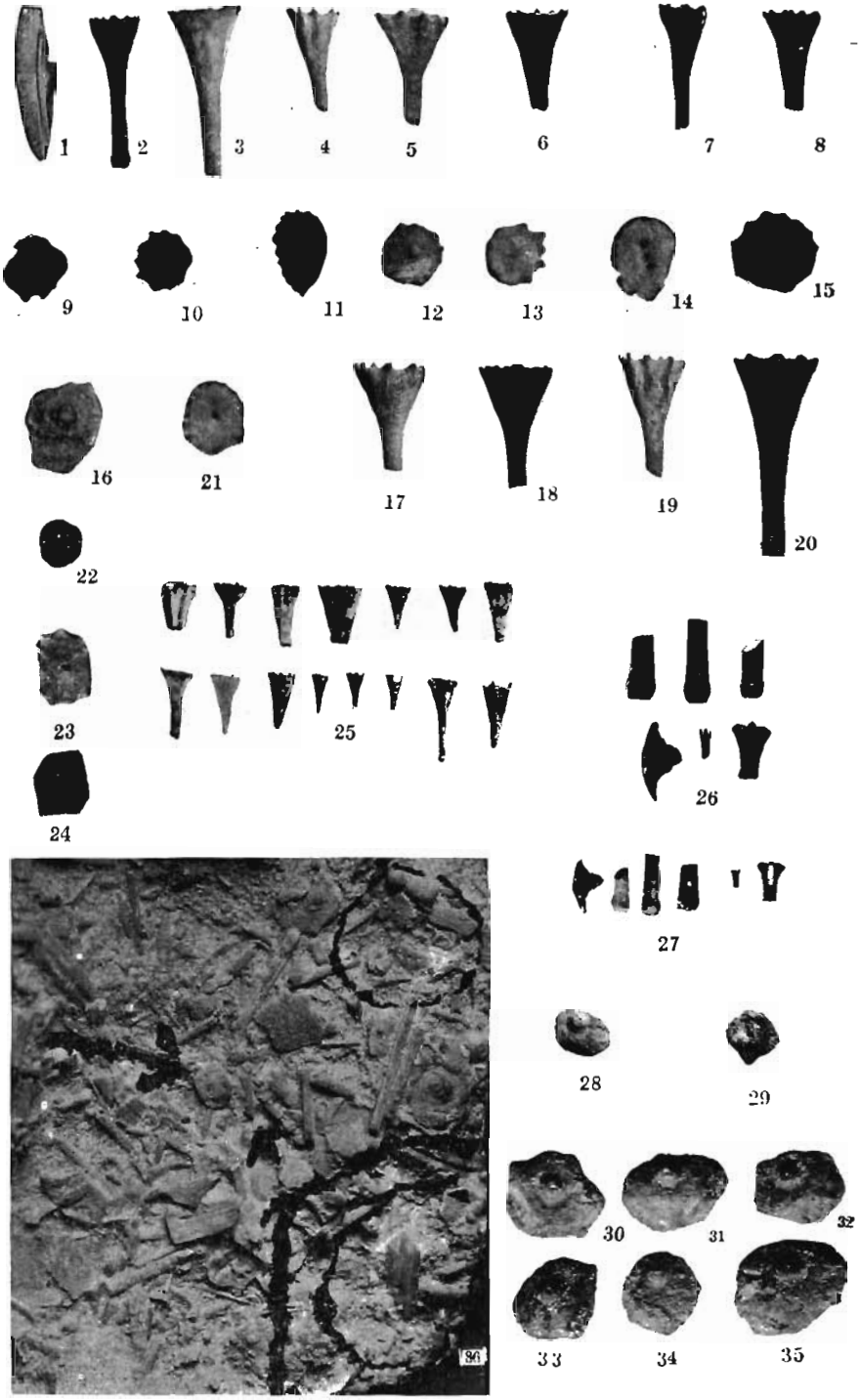
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PLATE LI.

Devonocidaris jacksoni Thomas.

Drawings by O. T. Walter, based on specimens from Bird Hill collected by A. O. Thomas.

Figs. 1-3. Side, face, and inner view of a half pyramid. Note the ridges for the attachment of the interpyramidal muscle, the retractor muscle scar, the rather deep foramen magnum, and the dental slide, about x6. (U. I. C. 3024.)

Fig. 4. Inner face of a half pyramid showing the triangular wing and tooth slide, about x6. See Plate LIII, fig. 2. (U. I. C. 3004.)

Fig. 5. Face view of a pyramid, restored and greatly enlarged; the foramen magnum should be wider.

Fig. 6. Similar to number 4, about x12; a part of the thin edge of the face next to the dental slide is broken away.

Figs. 7, 8. Two braces, x8.6. They are more slender than those of *Nortonechinus* (U. I. C. 3016.)

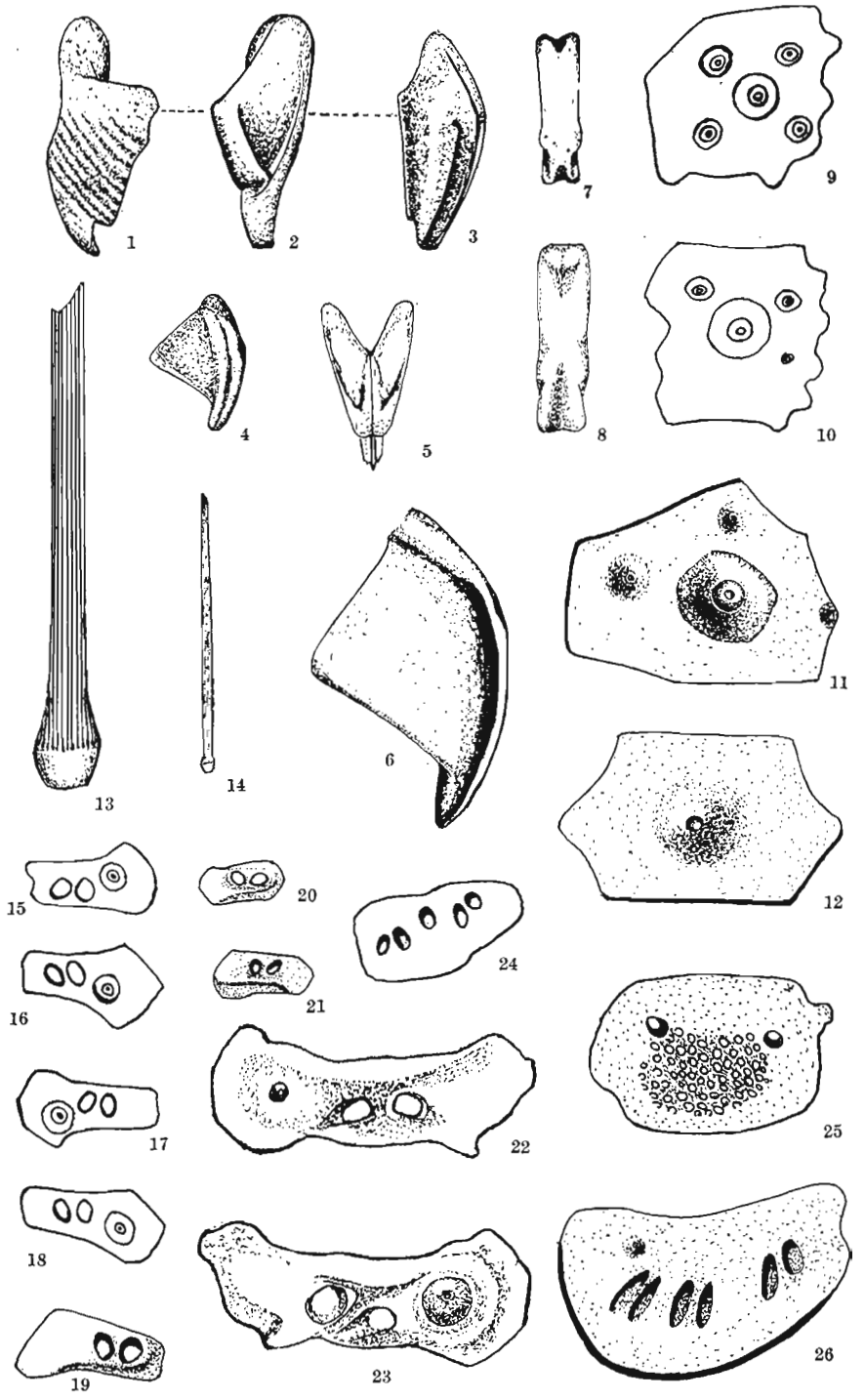
Figs. 9-12. Interambulacral plates, more or less broken; the first two x6, the last two x8.6. Note the distribution of primary and secondary tubercles, the parts of the primaries, and the terraced secondaries. The right borders of 9 and 10 are scalloped, they are thought to be adradials, their left margins are imperfect. Number 11 is much broken but shows well the low basal terrace. Number 12 is a nearly perfect hexagonal plate; it has little evidence of secondaries. See Plate LIV, figure 1. (Slabs 3012, 3005, 3010, and 3011 respectively.)

Fig. 13. A broken primary spine greatly enlarged. (After slab 3014.)

Fig. 14. Primary spine, about x2. (After slab 3008.)

Figs. 15-23. Ambulacral plates showing pore-pair, terraced tubercle, bevel, et cetera.

15. On slab 3013, x6.
16. On slab 3014, x6.
17. On slab 3013, x6.
18. On slab 3013, x6.
19. Inner surface; shows slight bevel, x7.7, on slab 3028.
20. A supposed demiplate with faint epipodium, x7.7, on slab 3001.
21. Another demiplate, x7.7.
22, 23. Ambulacral plates from screenings in the *De-*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vonocidaris horizon. Greatly enlarged; may not belong to this species.

Fig. 24. A compound plate with five oval pores, about x20. (U. I. C. slab 3001.)

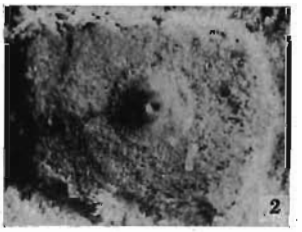
Fig. 25. Madrepore plate, about x17. See Plate L, fig. 36. (U. I. C. slab 3001.)

Fig. 26. A compound plate with elongate oval pores arranged in pairs, the three pairs forming a broad arc, x8.6. (U. I. C. slab 3010.)

PLATE LII.

Figs. 1-4. *Devonocidaris jacksoni* Thomas.
All from Bird Hill, A. O. Thomas.

1. Part of surface of slab x2.2, showing interambulacral plates, teeth, spines, and so forth. (U. I. C. 3020.)
2. Interambulacral plate showing primary tubercle and basal terrace, about x8. Same plate at lower center of figure 4. (U. I. C. 3020.)
3. Imperfect interambulacral plate showing faint basal terrace and a few scattered secondary tubercles, about x8.4 (U. I. C. 3006.)
4. Part of surface of same slab as figure 1, about x4.3. Note the jumble of plates and spines in upper left hand corner. About one-half inch to left of "4" is an ambulacral plate; there are three others near anterior margin of the brachiopod shell in the lower center.



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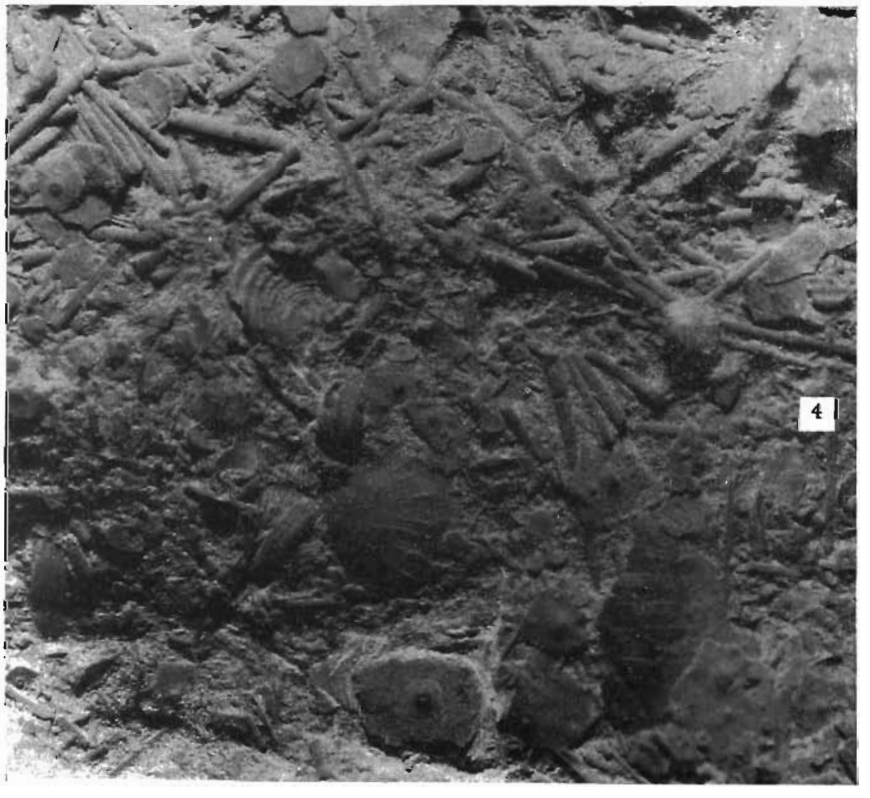

PLATE LIII.

Figs. 1-7. *Devonocidaris jacksoni* Thomas.
All from Bird Hill, A. O. Thomas.

1. Part of maxilla showing oblique ridges on the interpyramidal face. About x4. (U. I. C. slab 3043.)
2. Inner face of right half-pyramid showing the prominent triangular lateral wing, the longitudinal curvature of the outer face, the tooth slide, and the pyramidal suture. About x2.5. (U. I. C. slab 3004.)
3. Part of surface of a slab showing the fine spines, outer face of a tooth, and small plates. About x2.3. (U. I. C. slab 3005.)
4. Interambulacral and a tuberculate ambulacral plate; note shape and position of the pore-pair. Note also the slender tooth near the right margin, x4.3. (Part of slab U. I. C. 3013.)
5. Interambulacral plate with faint basal terrace and two or three small secondary faintly terraced tubercles; also ambulacral plate seen from below. About x4.5. (U. I. C. slab 3011.)
6. Part of slab bearing various parts of test and lantern. Note the two left half-pyramids showing retractor muscle scars, angle of foramen magnum, and pyramidal suture; near tip of arrow in lower left hand part of figure is a compound plate with five perforations, the specimen is somewhat broken, x4.5. (U. I. C. slab 3039.)
7. Slab which is largely a conglomerate of the remains of this species. Note ambulacral plate with suggestion of a peripodium; also the maxillae, teeth, spines, etc., x4.5. (U. I. C. slab 3016.)

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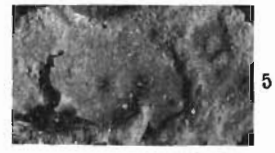

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PLATE LIV.

Figs. 1-6. *Devonocidaris jacksoni* Thomas.

All specimens from the Lime Creek shale at Bird Hill, collected by A. O. Thomas.

1. A hexagonal interambulacral plate with low primary tubercle and but little evidence of any secondaries, about x4. See Plate LI, fig. 12. (U. I. C. slab 3011.)
2. Interambulacral plate, probably an adradial; note the adhering miliary spines and secondary tubercles, about x2.5. (U. I. C. slab 3015.)
3. Maxilla, inner view showing tooth slide, x4.5. (U. I. C. slab 3040.)
4. Surface of a typical slab showing spines, plates, etc. At the tip of the arrow are three very slender spines, probably secondaries, about x4.5. (U. I. C. slab 3008.)
5. A slab crowded with spines, teeth, and plates. Note the markings on the inner face of the large tooth, also its point: median depression is well brought out on the face of the tooth above this. About x4.5. (U. I. C. slab 3020.)
6. Part of slab to show a long but incomplete primary spine. The specimen is 11.2 mm. long. Note also the ambulacral plate, x4.25. (U. I. C. slab 3014.)

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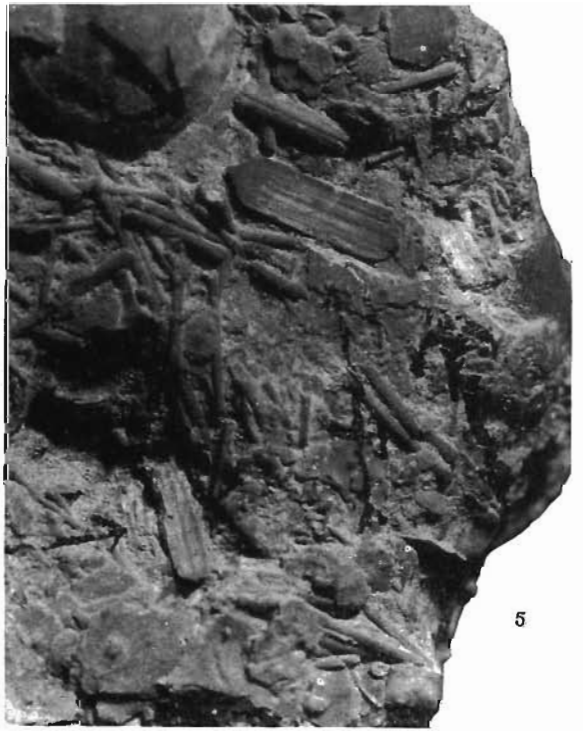

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